The Precision Rifle B.I.B.L.E

(Ballistics in Battlefield Learned Environments)

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3rd Ranger Battalion 75th Ranger Regiment Deadliest Sniper

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Contents

“*There is nothing wrong with a first shot miss at extended ranges, the importance of being able to see your own shot, adjusting, and making a hit on the second shot follow up before environmentals change is an art that must be understood and achieved in precision shooting.*”

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CHAPTER 1

“THE PRECISION RIFLE”

The precision rifle itself is based on a few key factors in order to in fact make it a “precision rifle”. Unlike some of the basic rifle you can buy at your local Wal-Mart, the cumulative factors that make up a precision rifle must be at a higher quality. Along with the quality of the rifle and its specifications, your ammo must also be of higher quality ammo as well.

The Precision Rifle Barrel

The barrel of a precision rifle, are what I believe to be the key component in the rifle itself. The barrels are precisely manufactured of a heavier cross section than your off-the-shelf rifles in order to reduce the change of impact points as the barrel gradually warms. Unlike the military assault rifle barrels, the barrels are not chromed to avoid inaccuracy due to uneven treatment.

When the rifle barrels are installed into the rifle stock itself, they are to be free-floated: i.e., installed so that the barrel is to only make contact with the rest of the rifle at the receiver. The ends of the barrel are crowned or machined to form a rebated area around the muzzle to avoid asymmetry or damage, and consequent inaccuracy if the end of the barrel should make contact and damage.

Some precision rifles may also have external longitudinal fluting. The fluting contributes to the heat dissipation by increasing the surface area, while at the same time decreasing the weight of the barrel.

You may also find that a precision rifles barrel may also utilize a threaded muzzle or a muzzle brake or flash suppressor and attachment mount. The threaded muzzle allows the shooter to attach a sound suppressor, while the muzzle break reduces significant recoil felt as the rifle fires. The suppressors often have a means to adjust for the point of impact while fitted, although I have seen some that may have a change of impact as much as 1 minute of angle (MOA).

A precision rifle barrels mainly use a four-grooved, right hand twist rifling that makes a full rotation in 10 or 12 inches. Most military sniper

rifles have a length of 24 inches or longer, in order to allow the propellant within the cartridge to fully burn and thus reducing the amount of revealing the muzzle flash and increasing the muzzle velocity. Although, some rifles may use shorter barrels to improve the mobility of the shooter. Shorter barrels' velocity is loss is irrelevant at closer ranges when the projectile energy is more sufficient.

The heavy bore precision rifles are a growing trend in the precision rifle community. A Heavy bore rifles are intended to lessen the warpage as the barrel temperature increases when fired over a period of time with short intervals between each shot, thus lessening the departure from your original zero. The "thicker" heavy barrels also give the barrel a greater outer surface area, thus giving the barrel better cooling capabilities.

Accuracy

The accuracy of the precision rifle is commonly described as minutes of angle (MOA), which we will discuss in greater detail later. Law enforcement rifles are most commonly capable of a 1 MOA or ½ MOA accuracy (approximately a 1 inch group at 100 yards, or ½ inch group at 100 yards). Law enforcement and military precision rifles need to be at least capable of yielding 1 MOA, due to the nature of shot placement on a target. Please note that just because the rifle manufacture promotes a 1 MOA rifle, the shooter still needs to practice and understand the full dynamics of precision shooting in order to achieve its potential 1 inch group at 100 yards. Although, there are some rifle manufactures claiming to yield less than ½ MOA rifles, the average less than 20 percent of shooters can actually produce less than ½ MOA.

Time and time again, I have come across shooters equipped with a high end rifle with ½ MOA, and yet the shooter produces 2-3 and sometimes even 4 inch groups at 100 yards. This simply comes down to the lack basic shooter fundamentals, and practice. Ultimately, a rifle yielding anything worse than 1 MOA, is potentially asking for problems downrange as the distance increases when precision is needed on smaller or partially exposed targets.

A 1 MOA (0.3 mrad) average extreme spread for a 5-shot group (meaning the center-to-center distance between the two most distant bullet holes in a shot-group) translates into a 69% probability that the bullet's

point of impact will be in a target circle with a diameter of 23.3 cm at 800 m (about 8 inches at 800 yards). This average extreme spread for a 5-shot group and the accompanying hit probability are considered sufficient for effectively hitting a human shape at 800 m distance.

Understanding the MOA (Minute of Angle)

1 MOA=approximately 1 inch 3-5 round group at 100 yards (for shooter preference). 1 MOA in a 3-5 round group at 100 yards IS: 1.047 inches at 100 yards to be exact.

“A minute of arc, arcminute, or minute arc (MOA), is a unit of angular measurement equal to one sixtieth (1⁄60) of one degree (circle⁄21,600), or (π⁄10,800) radians. Since one degree is defined as one three hundred and sixtieth (1⁄360) of a rotation, one minute of arc is 1⁄21,600 of a rotation. It is used in those fields which require a unit for the expression of small angles, such as when referring to marksmanship.”

The MOA is the angle of an arc expressed in number of degrees. There are 360 degrees of arc to a full circle. Each degree consists of 60 minutes of arc. The distance covered by the measure of arc is relative to the circumference (total distance around the circle) it is contained within. Knowing the radius (distance to center of circle) circumference is easily calculated by using the constant pi . The ratio (represented by pi) of circumference is constant to diameter (radius x 2) regardless of circle size. The precise value of pi is so far unknown to man but is normally resolved to 3.1416 or 3.141 for our purposes. Rifle manufacturers and gun magazines often refer to this capability as sub-MOA, meaning it shoots less than 1 MOA. This means that a single group of 3 to 5 shots at 100 yards, or the average of several groups, will measure less than 1 MOA between the two furthest shots in the group, i.e. all shots fall within 1 MOA. If larger samples are taken (i.e., more shots per group) then group size typically increases, however this will ultimately average out. If a rifle was truly a 1 MOA rifle, it would be just as likely that two consecutive shots land exactly on top of each other as that they land 1 MOA apart. For 5 shot groups, based on 95% confidence a rifle that normally shoots 1 MOA can be expected to shoot groups between 0.58 MOA and 1.47 MOA, although the majority of these groups will be under 1 MOA. What this means in practice

is if a rifle that shoots 1" groups on average at 100 yards shoots a group measuring .

In the precision shooting community, we often assume that because we have a 1 MOA rifle and we are capable of shooting a “1 inch group at 100 yards, that our rifle will continue to hold that MOA exponentially. Though I’m sure it may be possible to, due to various variables that we cannot account for to its finest, due not always expect the MOA to increase 1 inch or ½ inch exponentially as the distances increase.

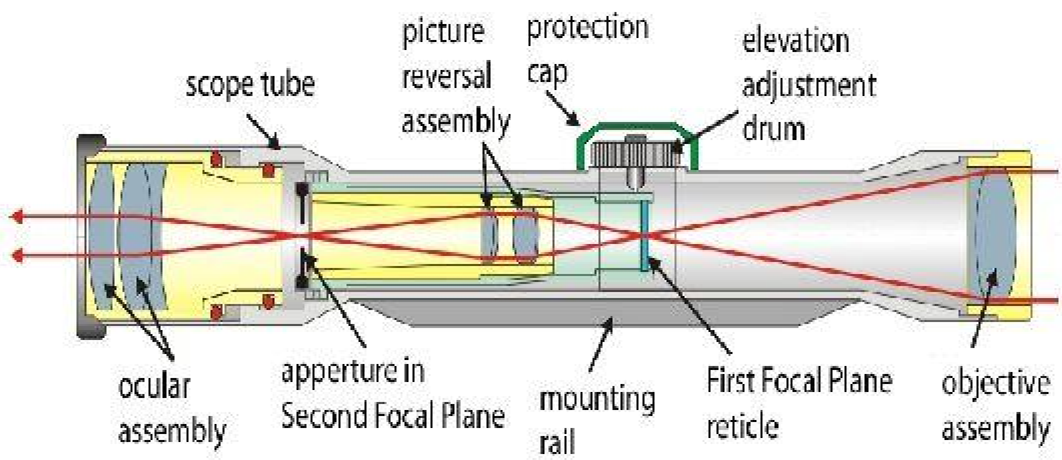
CHAPTER 2

“UNDERSTANDING THE SCOPE”

There are various types of rifle scopes on the market today, but finding what fits your needs for precision shooting is more of a shooter preference. Here we will discuss the breakdown of the sniper scope and the most common types of scopes being used in the precision shooting community.

Understanding the Scope (MIL Dot)

The rifle scope is basically a telescopic sighting device that is based on an optical refracting telescope. Rifle scopes used for precision shooting are equipped with various graphic image patterns (reticle) mounted in an optically position in an optical system to give the shooter an optical aiming point and unit of measure. Precision rifle scopes are classified in terms of the optical magnification and the objective lens diameter, for example, a 10x50. The term 10x50 denotes the 10 times magnification within a 50mm objective lens. The larger the objective lens diameter, provide the shooter with a brighter image, due to the ability to gather more light with the lens.



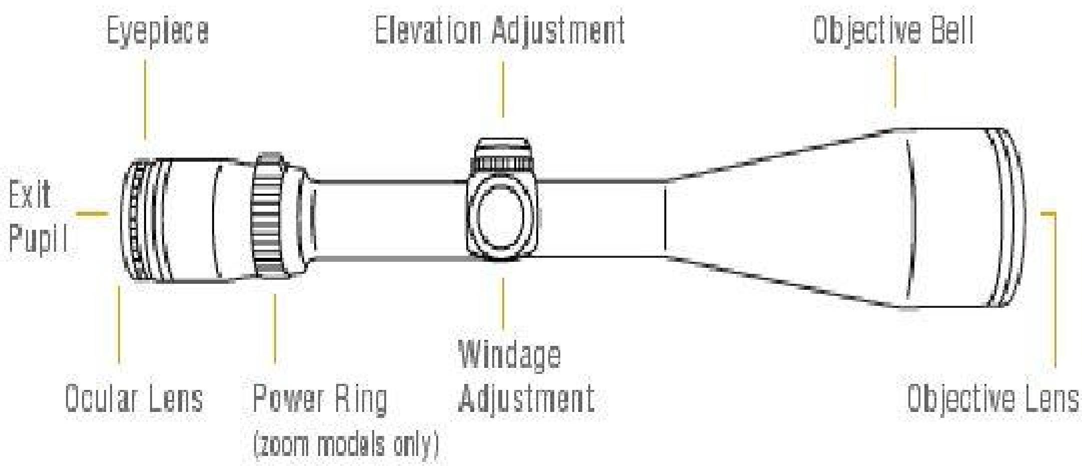
Reticle Focal Plane

Rifle scopes are based on refracting telescopes using image erector lenses to present the shooter with an upright image have two planes of focus where the reticle can be placed, at the focal plane between the objective lens and

the image erector lens (First Focal Plane (FFP)), or the focal plane between the image erector lens system and the eyepiece (Second Focal Plane (SFP)). Scopes that are on a fixed power, there is no significant difference, but scopes that are capable of varying in power; this is where it presents the shooter with things to consider. A first focal plane scope, the reticle expands and shrinks along the image as the shooter adjust the magnification. The second focal plane scope, the reticle would appear the same shape and size while the image grows and shrinks.

The main disadvantage of the second focal plane designs comes with the use of range estimation, wind holds, and hold overs and hold unders when utilizing the mildot reticle. The problem comes with the proportion between the reticle and the target is dependent on selected magnification, these reticles will only work properly at one magnification, usually being the 14 or highest power. The first focal plane designs are not susceptible to magnification-induced errors, they have their own disadvantages. It's challenging to design a reticle that is visible through the entire range of magnification e.g. a reticle that looks fine and crisp at 24x may be very difficult to see at 6x magnification. While taking this into consideration, a scope with a reticle that is fairly easy to at a 6 magnification, may also be thick enough at a 22 -24 magnification to make a precision difficult.

Variable power telescopic sights with first plane reticles have no problems with point of impact shifts. Variable power telescopic sights with second focal plane reticles can have slight point of impact shifts through their magnification range caused by the positioning of the reticle in the mechanical zoom mechanism in the rear part of the telescopic sight. Normally these impact shifts are insignificant but make accuracy oriented users, that wish to use their telescopic sight trouble-free at several magnification levels, often opt for first focal plane reticles. Around the year 2005, Zeiss was the first high end European telescopic sight manufacturer who brought out variable magnification military grade telescopic sight models with rear second plane mounted reticles. They get around impermissible impact shifts for these sights by laboriously hand adjusting every military grade telescopic sight.



Elevation Turret

The elevation turret, is located at the top of the scope, sometimes referred to as the ballistic Drop Compensation (BDC), shifts the bullet impact up or down. The elevation turret compensates for the effect of gravity on the projectile at given distances in a flat line of sight. The elevation turret must be "calibrated" for the particular ballistic trajectory of a particular combination of the rifle and cartridge at a predefined muzzle velocity and air density. This process is known as "zeroing the rifle." With increasing range inevitable BDC induced errors will occur when the environmental and meteorological circumstances deviate from the predefined circumstances for which the BDC was calibrated.

Windage

The horizontal adjustment on the right side of the scope. The windage turret operates in the same manner as the elevation turret, but only shifts the bullet impact on the horizontal plane. If the turret is in .25 or .5 MOA adjustments, at 100 yards, by rotating the turret toward or away from you will move the bullet impact left or right .25 or .5 inches.

Parallax

Parallax problems result from the image from the objective not being coincident with the retile. If the image of the objective is either in front of or behind the reticle, then putting your eye at different points while looking through the ocular lens, the reticle appears to be at different points on the

target. To better understand this, imagine a person 10 feet in front of you is holding out a pencil so that the tip of the pencil is centered on his chest. From your position in front of him, as you move your head left or right, up and down, the tip of the pencil that appeared to be on his chest is now moving at various points on his body. In order to keep the tip of the pencil on his chest, he would need to touch the tip of the pencil on his chest instead of holding it in front of him.

Parallax operates in the same way. You want to adjust the parallax so that the reticle does not appear to be floating on the target when you slightly shift your heard left, right, up, and down while looking through the scope. The parallax will often change as range increases. If you were to adjust your parallax at 100 yards and then move to 500 yards, your parallax would more than likely need to be adjusted. This optical effect may cause a parallax induced miss when shooting targets at distance when parallax is not adjusted.

Sight Picture

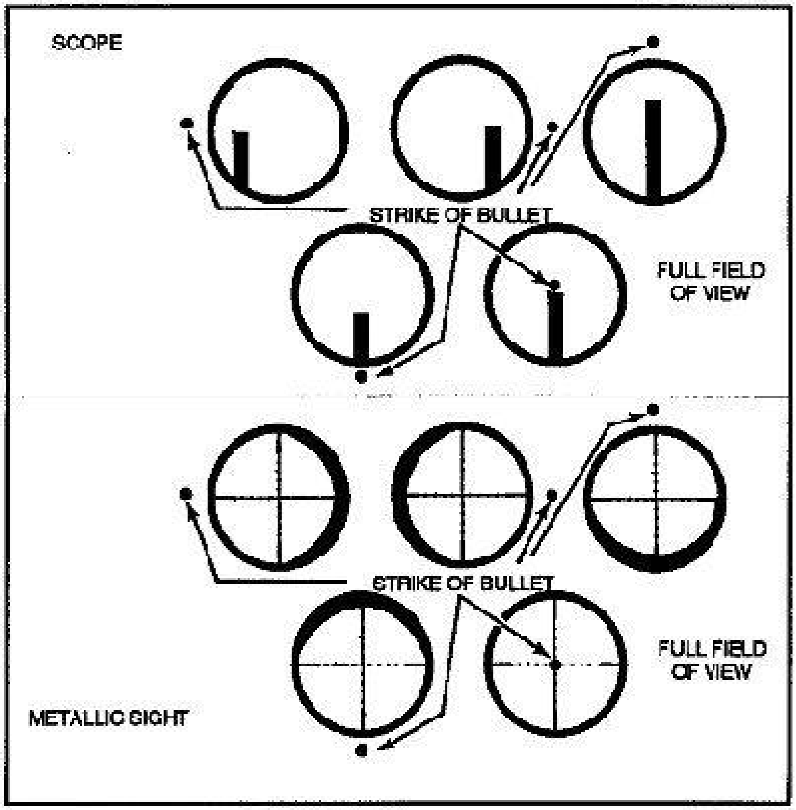


Figure 3-17. Sight alignment.

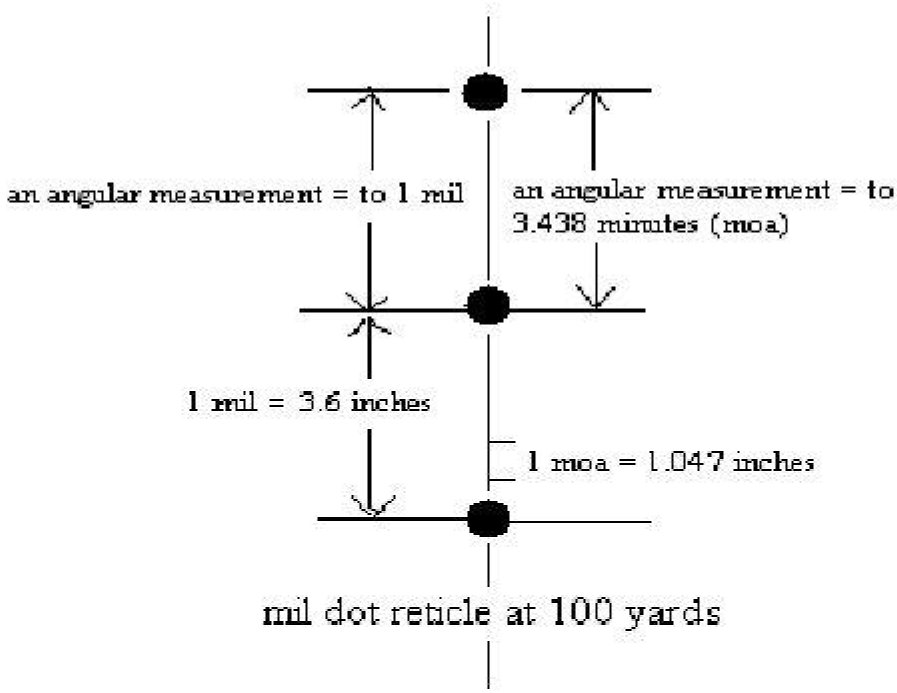
Magnification

The magnification knob is meant to change the magnification by turning a ring that is generally marked with several numbers indicating the magnification power levels.

MOA and MIL Adjustments

Elevation turrets are most commonly adjusted in ½ and 1 MOA or MIL adjustments. When utilizing a turret that adjusts in MOA, turning the turrets elevation or windage will move the bullet impact vertically or horizontally the prescribed MOA distance. For an example, if your turret adjust in ½ MOA, one click will change the bullet impact approximately one half inch at 100 yards, one inch at 200 yards, 1 ½ inch at 300, etc.

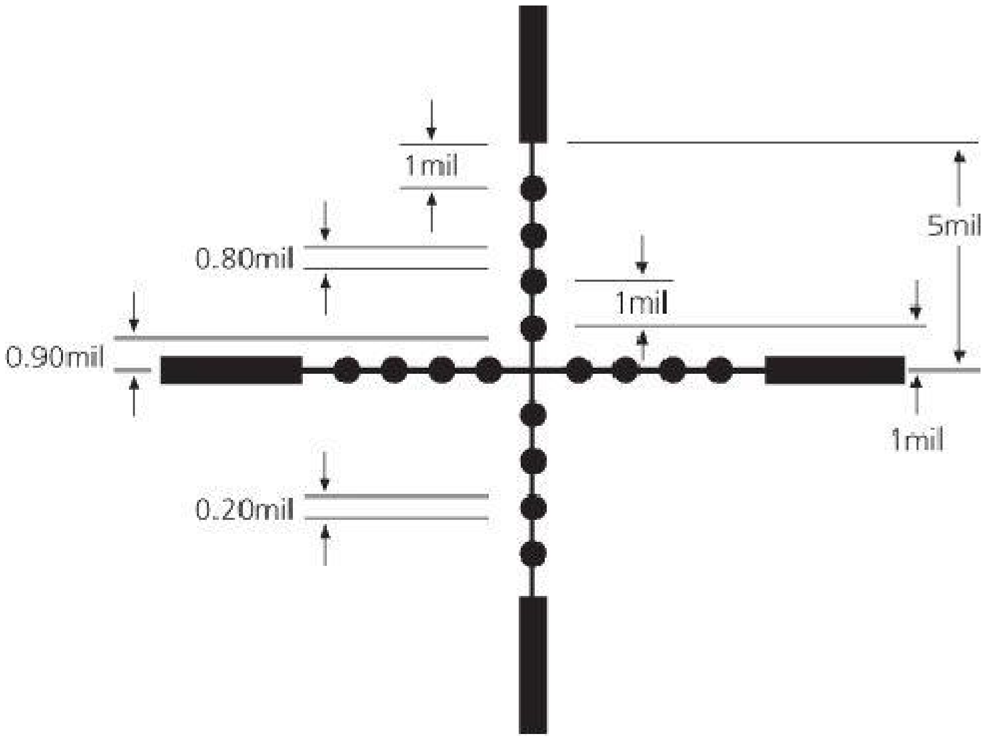
When utilizing the MIL adjustments, at the very basic level of understand, a MIL, 1 MIL equals 3.43” at 100 yards (for shooter preference we use 3.6”). Although this may seem like a lot, most MIL optics have 1/10 MIL adjustments so that each click equals 1/10 of a MIL, or .34 (approximately .36”) at 100 yards.



MOA MIL Scope vs. MIL/MIL Scope

One of the most common questions I get asked is the choice of scope they should use? Its seems that the world of precision shooting is shifting from the MOA MIL dot scope to the MIL/MIL Scope, meaning a scope that has MIL adjustments with matching a MIL reticle. For those shooters who are used to the traditional MOA adjustment scope, it may seem like “new world” of math and retraining, when in fact, it’s not. Let’s think about a normal typical shooting situation. You start off by sighting in your rifle at a distance of 400 yards and apply all the fundamentals of marksmanship to the best of your ability. Your bullet impacts 6” low. Being that you are 400 yards away, you would divide 6 by 4 and get the answer 1.5. You then come up on the elevation approximately 1.5 MOA or 3 clicks on a ½ MOA scope. The next shot you fire hits your target. Not too bad for an MOA scope, you simply do a little math.

Now we can take a look at our MIL/MIL scope with 0.1 MIL adjustments on the same 400 yard line. You fire a shot and you see that the round impacts .4 MILs low. Instead of doing any math in your head, you simply reach up and dial up 4 clicks (0.4). The next shot you fire is dead on. No math involved, what you see is what you get. This can be applied at any distance. If you see that the bullet impacts 0.7 MILs low at a given distance, you simply dial in 7 clicks on your 0.1 MIL elevation turret. (Reticle breakdown below in Diagram B.)



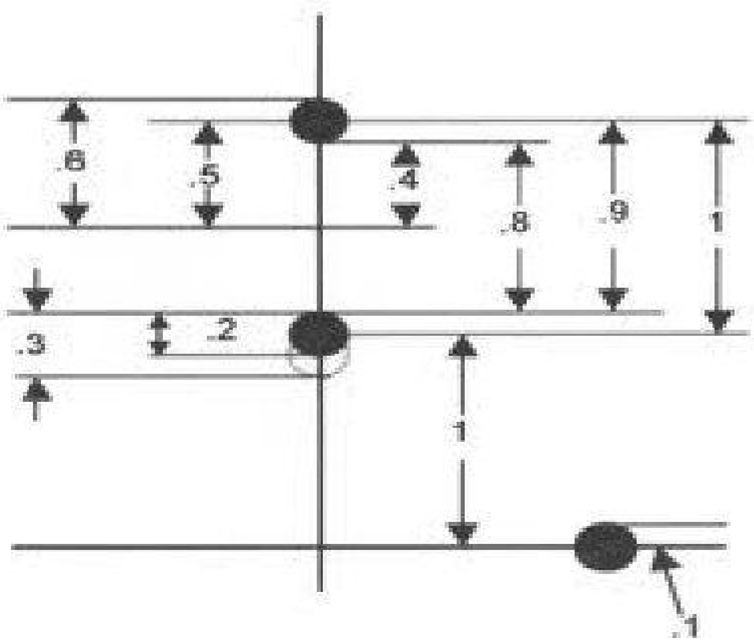


Diagram B.

What scope is best for you?

This is in my opinion a personal shooter preference. With saying that, let's take a look at the benefits of both, and apply them to a shooting scenario.

What if your apart of a sniper team currently deployed to a hostile environment. You and your spotter see a target of opportunity and given permission to engage from your sniper position. Your laser range finder (LRF) was destroyed during your infill so you resort to doing some basic MIL Dot range estimation based on his height. You send your first shot downrange and you spotter sees the bullet impact, he quickly calls out to you, ".6 MILs high, .4 MILs right." Without doing any math as you would with the MOA to convert it to inches, you simply dial down the elevation 6 clicks and hold for the wind .4 left. When taking a look at it in this fashion, you can see that when distances may be unknown, you do not have the ability to always use an LRF, or your MIL DOT range estimation is off due to various environmental such as mirage or angle to target, the MIL/MIL would be best for you.

CHAPTER 3

“Precision Rifle fundamentals”

Precision rifle fundamentals are commonly overlooked, or not emphasized enough as they should be when it comes to training. Precision shooting by definition, is being able to have the ability to shoot in a state of quality being precise with exactness and being able to reproduce that exactness consistently. In order for us to be extremely precise (within the capabilities of the rifle) consistently, we must understand the importance of the fundamentals.

The beginning of every shot that we take starts and ends with the basic fundamentals of shooting. The fundamentals are broken down into specific categories that we will discuss and stress upon.

Body Alignment

This is where the very start of the fundamentals should be stressed. The importance of body alignment is absolutely crucial when precision shooting, and where many shooters tend to fall back on “old school” shooting techniques this needs to be addressed properly. Improper body alignment can cause an assortment of problems downrange, and relate to an assortment of problems such as a miss, bi-pod hop, reticle within the scope coming off target, etc.

Now the question presents itself, “what is the correct body alignment?”

Unlike the most common body position and alignment that we so often see, and some more than likely do, where the body is off to an angle behind the rifle as we lay in the prone, we need to be perfectly straight back behind it. When the body is slanted off of the rifle to the left or the right, we are giving the rifle angles that through physics, the rifle will exploit during recoil.

When the rifle is given an angle, it absolutely will exploit it and cause the rifle to “hop”, or “jump” off target. While understanding the process of

recoil, we also need to understand how basic physics applies to this as well. Rifle recoil is a result of momentum conservation, which is an extremely important fundamental principle. Momentum is characterizes an objects resistance to change in motion. If this motion is along a “straight line” we call it linear momentum; if it is rotational motion we call it angular momentum. The basic idea is the same, moving objects like to keep moving and to only change their motion we have to apply a force or an angle to it. If no force is present, then the momentum doesn’t change, it is conserved.

Now understanding this, we can see that when the rifle is fired and the gun recoils, we know that a projectile is exiting the barrel at a high rate of speed and under pressure in a straight line, thus causing the rifle to recoil straight back to the rear. Unless we give the rifle a reason to shift left or right, or jump off of the bipod legs, then it is only because we have given the momentum of the rifle an angle with our body to work against. Imagine the rifle being clamped on a vise, and the vise is attached to a trolley on wheels. When the rifle is fired, the trolley will only move in one direction, and that direction is straight back.

In order to ensure that we are straight back behind the rifle, there is a simple step by step process we can do when given time and opportunity.

The first step is to set up your rifle so that it is facing downrange in a safe direction at your target. Ensure that the rifle is unloaded, cleared, and chamber is checked.

The second step is to stand completely up behind your rifle with your feet square, slightly more that shoulder width apart, and slightly offset to the left or the right of the rifle butt stock so that if you were to draw an imaginary line from your firing shoulder to the rifle butt stock, it will align. While checking this, also ensure that if you were to draw another imaginary line between your feet, and another line from the butt stock to the line in-between your feet, you should have them intersect at 90 degrees.

Now that we have the first two steps accomplished, drop down to your knees while maintaining a 90 degree angle between your knees and the butt stock. Once you are positive that you are still square behind the rifle, you can lie down and place the butt stock into your shoulder pocket. Be sure to resist the urge to shift your hips left and right to get comfortable. The

reason it is feeling awkward is simply because you trained your body and mind as to what feels “comfortable”. In order for us to start to feel comfortable behind the rifle while straight back behind the rifle, we have to practice, practice, practice, until we have built it into our minds. If you have the ability to go and shoot with a spotter, or partner, have them check to see if your body is straight back behind the rifle.

Once behind the rifle, I tend to see shooters angling their non-firing elbow so that the tip of the elbow is pointed towards the target. This is something else to avoid. The elbows should as well, have a 90 degree angle in relation to rifle, just as the feet and knees described earlier. As precision shooters, we need to start thinking in terms of physics, and angles. Please note that giving various shooting circumstances, may it be terrain, time, etc. you will not always be able to lay perfectly straight back behind the rifle. This will be discussed in later chapters when discussing positional shooting. This body position must first be mastered in order to properly under the physics and fundamentals of precision shooting.

Natural point of aim

Exactly what is “Natural Point of Aim, or NPA?” Natural point of aim is described as a shooting skill where the shooter minimizes the effect of body movement on the firearm’s impact point. Natural point of aim is based on the idea that muscular control is insufficient to provide a stable platform for shooting, especially more than one shot. The shooter must rely on non-muscular support to provide a good shooting platform. This definition can be simply summed up by knowing that the rifle must me pointed to the target, and the body toward the rifle!

In order to test or make sure that you have a good natural point of aim, there are simple test that you will need to do, one being a gross adjustment, and one being a fine adjustment.

The first and most common test of natural point of aim, is the gross adjustment. Once the shooter is straight back behind the rifle, and the reticle is on target, he or she can simply close their eyes, and take three to five breathing cycles. Once the shooter opens their eyes, the reticle should

not move. If the reticle is off target from the original point of aim, the shooter must make small body adjustments as one unit with the rifle, keeping the spine and body position straight. The spine must maintain a parallel line with the bore of the rifle.

Now that we have a good gross adjustment for NPA, we need to fine tune it. We can fine tune our NPA by conducting a few dry fires. A dry fire is conducting with no round in the chamber, and ensuring that the rifle is empty. When dry firing, make sure to treat every "dry shot" as it were a live round, never miss an opportunity to train. Be sure to focus on the reticle when the trigger is pulled. Many, if not all shooters that have dry fired a rifle, have noticed that the reticle may jump, or shift. If the reticle does shift or jump, when you hear the "click" of the hammer fall, then the rifle is telling you where it needs to be. The reticle jumping or shifting, is giving you a sign as to where the bullet impact will strike on target. In order to overcome this, once again we need to adjust our body alignment as we did with the gross adjustment for NPA. While making the small adjustments, continue to ensure that we are continuing to shift as one unit with the rifle.

Proper Influence on the Rifle

When talking about the proper influence on the rifle, we are talking about the amount of "muscular tension" applied to the rifle. Some shooters believe that the more muscular tension and influence one has on the rifle, the less impact the rifles recoil has on the individual, or they become more stable. Muscling the rifle, or fighting the rifle when shooting, causes an undo tremor in one of the most important extremities that we have when precision shooting, this being the arms. The only tension that we should have, is the tension in the bicep as it holds the rifle snug and straight back to the rear. Be sure to isolate the bicep muscle and make it an independent component, the rest of the body should be relaxed, nothing more than a slab of meat behind the gun.

The influence of the firing hand on the rifle must also be understood. With rifles such as the Accuracy International (AI), and the SR-25 there is something shooters refer to as the "grip". Although the nomenclature suggests that it is in fact a grip, it is something that we need to not be influenced by due to its name. In fact the "grip", should in fact be called a

hold. “Gripping the grip” is an undue and un needed influence on the rifle. The shooters firing hand should only utilize the grip to simply support the rifle in place and to firmly seat the butt stock of the rifle into the shoulder pocket.

Breathing

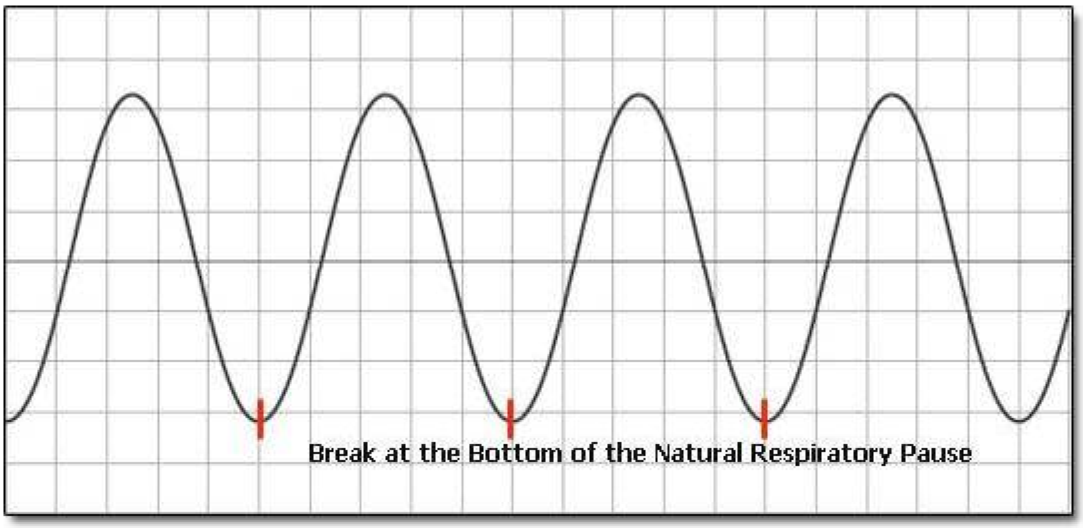
Breathing, how and when to break the shot is a common fundamental that is often misunderstood in precision shooting. I’m sure that as we were taught growing up or in some sort of shooting school, we were taught to take a few breaths, let the air half way out, hold your breath, and squeeze the trigger.

Why do we hold our breath? Is it because it makes us more stable and calm while the reticle rest on the target? If this were the case, and holding our breath makes us more stable, wouldn’t we want to hold our breath while driving down the road at 70 M.P.H. with multiple vehicles passing within 18”-24” in the opposite lane from our vehicle with a combined closure speed of 140 M.P.H.? This would be a fatal accident! Instead when we are driving, we aren’t holding our breath, some are changing radio stations, talking on the cell phone, etc., all while continuing to breath. If holding your breath makes one stable, this would definitely be the time to do it. The human body naturally breaths on its own with a slight pause in-between the exhale and inhale of approximately 1.5 seconds. The reason we inhale again, is because our body starts to become oxygen deprived after the 1.5 seconds.

Sure we can hold our breath for longer, but for how much longer before our body starts to really fight for oxygen. When the body becomes oxygen deprived, the first thing that is affected, is our eye sight. The eyes will begin to flutter and shake, and if we continue to hold our breath, the vision starts to go. With this being the case and we need our eyes to see and shoot, why interfere with the eyes by holding your breath. The simple way to defeat this is to breath from the start to the end while shooting.

The question is now presented, “where do we break the shot within our breathing cycle?” While in your breathing cycle, take note of the rise and fall in the chest and where the natural respiratory is. The natural respiratory pause is where the shot should be taken. During this pause, know that it is a

pause and not a hold. Once the shot is broken at the bottom of the cycle at its pause, your body will continue the cycle “naturally.” When shots are broken at various points in the breathing cycle, such as the top, bottom, and in between, shooters will notice a change of bullet impact on targets at distance, as much as 20-40 inches vertical at extended ranges (600-1000 yds.).



Proper Trigger Control

The correct manipulation of the trigger is absolutely a very important topic that needs to be discussed in its fullest capability. Time and time again, watching many shooters of various levels of skill and experience behind the rifle, at 100 yards on a one inch dot, shooting a 5 shot group with top of the line scopes, ammunition, and rifles, shooters see that there group will not maintain a .5 or 1 MOA. The groups downrange tend to have a shot group with as much as a 2-4 inch dispersion in the horizontal plane. Though the shooter feels that everything is correct, and the fundamentals were applied correctly to the best of their capability, they cannot seem to understand the dispersion of rounds in the horizontal plane. Could it be caused by spin drift, Coriolis Effect, wind, humidity, etc? The answer is no, it is the shooters neglect to properly operate the trigger correctly and coming straight back and to the rear. Many times we are told when shooting a rifle, to come straight back on the trigger, but never shown exactly what coming straight back on the trigger really is or looks like.

We may seem that we are coming straight back on the trigger, but if this were the case, shooters wouldn't have a string of rounds on target spread along the horizontal, we have trained our brains to shoot was is comfortable to us, and what appears to be correct.

Understanding how the rifle works in relation with physics, we can break down the trigger to see exactly why a shot group will have horizontal dispersion. The rifle is nothing more than a vibrating stick when fired, with the trigger mechanism acting in the same fashion as a tuning fork that sits within the rifle itself. Looking at the trigger mechanism as a "tuning fork", which is simply a hunk of machined metal that has two forks at the end, and when the tuning fork is struck it begins to vibrate. When the tuning fork is placed against a stationary object, the tuning fork bounces away. The trigger mechanism and rifle operate in the same manner. The trigger itself operates and moves in between two solid metal objects (Fig. A), known as raceways. With the trigger itself also being a solid object, if it is pulled in an uneven manner, when fired, the rifle will vibrate away from the trigger laterally!

Fig. A

In order for us to alleviate the trigger being pulled in any other way than straight back and to the rear, we have to look at shooting in means of angles, as we did with body alignment and how the rifle will exploit them. The trigger finger must move perpendicular to the bore of the rifle, simply

meaning that our finger must travel straight back at right angles to the bore. If your trigger finger is operating at any other angle than a right angle, the trigger will slide or hit against the raceways as the rifle vibrates. A change in our hand position is the only way that we can achieve a right angle trigger finger to the bore of the rifle.

Below are a few pictures of properly achieving 90 degrees on the trigger

Proper Follow Through

A proper follow through when precision shooting is the mental component of breaking the shot without disturbing the sights. Follow

through is the difference between knowing where the shot went and not knowing at all. Follow through is essentially what holds all the other elements of marksmanship together long enough for the bullet to make it out of the barrel. Without proper follow through, we may disturb the rifle while it is still in its recoil stage enough for us to push a bad shot. Be sure to let the rifle to finish its recoil process, fully, before jumping on the bolt to chamber a round. When using a semi-automatic rifle, be sure to let the recoil pulse fully finish before resetting the trigger reset.

CHAPTER 4

“External Ballistics”

External ballistics is the science of ballistics that deals with the behavior of the bullet or non-powered projectile while in flight after it exits the barrel before it hits its intended target. The behavior of the bullet is determined by various forces that act on upon it that we cannot control, shooters may refer to this as “environmentals”.

The external ballistics/environmentals are classified into multiple factors, but for the purpose of precision shooting, we will only discuss the following topics:

-Gravity

-Wind

-Ambient air density

-Altitude

-Ballistic coefficient

Gravity

The effect of gravity on a project from any firearm, also known as bullet drop, starts to take effect on the projectile as soon as it leaves the barrel of the rifle. The reason why rifle scopes (as well as iron sights) have elevation turrets, is to account for the effect of gravity on a particular round that is being fired. Depending on the velocity of the projectile, dictates how far it will travel before falling to the ground. Low velocity rounds, typically ranging from 800 feet per second (fps) to perhaps 1600 fps, such as pistols, .22 LR, etc. must travel a higher arc in its trajectory to reach a 100 yard target. The reasoning for the higher arc in trajectory, is too overcome the forces of gravity acting upon it. Think of it as throwing a football or baseball. If you want to throw the football as far as you can, you don’t throw in a straight line, if you were, the ball would fall short and hit the ground, no matter how fast or hard you throw it. In order for you to throw the ball as far as you can, you would “arc” it. The same concept applies to

a bullet. Although a high velocity round (2600 fps or more) won't have the same trajectory as a bullet with an 800 fps velocity, the trajectory still has an arc because gravity acts on all objects so it must be accounted for.

Wind

Wind is the main cause for horizontal projectile deflection and generally the hardest ballistic variable to measure and judge correctly. There are various means in judging and correcting for wind, which we will talk about in another chapter. For now, we need to understand that a bullets reaction to wind depends much on two variables, wind speed and the wind direction.

There are two key elements to understanding a bullet's susceptibility to wind drift. The first being the bullets ballistic coefficient (BC), which we will discuss later, which combines the air resistance of the bullet shape (drag coefficient) with its sectional density (the ration of its frontal surface are to bullet mass). The second being the bullets velocity. The concept of physics behind the bullet and wind, is that the longer the exposure to wind the bullet has, the more the bullet will drift, so the faster the bullet can reach its intended target, the less time wind will have a chance to effect it.

Ambient Air Density

Ambient air density is classified into three categories. Air temperature, pressure, and humidity.

Air temperature:

As the air temperature rises, the air density is lowered. Knowing that there is lease resistance, the velocity of the round will increase, causing the point of impact to rise. Note that this is in relation to which the rifle was zeroed. If you were to zero your rifle at 60 degrees and fire the rifle in a temperature of 100 degrees, the point of impact will rise considerably.

Barometric Pressure:

Barometric pressure is often referred to atmospheric pressure, and is the force that is exerted on objects by the weight of the atmosphere above them. Though we may think of gas as weighing not weighing on anything, it does in fact have mass. Because of this and the effect of gravity upon the

gas itself, the air above us and around us does weigh down on us, as it will in the same manner on a bullet. The barometric pressure is measured in the downward force that the atmosphere exerts per unit of measure in a certain given area. In the realm of precision shooting, the air pressure is less at higher altitudes and the air is less dense. Meaning that the bullet is more efficient due to less drag. Look at it in the terms of jumbo jets. When jumbo jets take off and reach an altitude of 30,000 feet above ground level where the air is less dense, they can average speeds of 580 m.p.h., while the same jumbo jet would have a hard time to achieve this speed at 20 feet above ground level, simply due to the fact that the air is more dense, thus creating more drag.

Humidity:

Humidity has a counter intuitive impact. Since the water vapor has a density of 0.8 grams per liter, while dry air averages approximately 1.225 grams per liter, the higher humidity decreases the air density, thus decreasing the drag on the bullet.

Density Altitude/Altitude:

Density altitude is perhaps the single most important factor affecting the bullets performance when shooting at extended ranges. Density altitude is the pressure altitude adjusted for non-standard temperature. Both an increase in the temperature and, to a much lesser degree, humidity will cause an increase in the density altitude. Meaning that in hot and humid conditions, the density altitude at a certain location may be significantly higher than the true altitude. This is important in the precision rifle field. Knowing that in higher altitudes, the bullet will experience less atmospheric drag, thus giving it the ability to fly faster and further, a high density altitude will do the same, even if your true altitude measure otherwise. In other words, the bullet doesn’t care, or mind in regards to true altitude; it will perform accordingly to what it feels as it flies through the air in “density altitude”.

Ballistic Coefficient (B.C.)

In ballistics, the ballistic coefficient of a body (bullet) is a measure of its ability to overcome air resistance in flight. A bullet with a high BC will travel farther and faster than one with a low BC because it is affected less by air resistance, retaining more of its initial velocity as it flies downrange from the muzzle. In a perfect world, the perfect bullet would have a ballistic coefficient of 1.0 (G1). The higher the BC, the flatter the bullets trajectory, arrives at the target faster, and delivers more energy than one with a low BC.

Ballistic Coefficients are classified G scale, such as a BC of G1, G2, G3, G4, G5, G6, and G7. Today, two drag functions, G1 and G7, are popular for commercial bullets. G1 is the drag function for a slightly modified standard bullet shape, and G7 is the drag function for long, slender bullets with long ogival points and boat tails, the so-called very low drag bullets. G1 is used widely by most bullet manufacturers, while makers of very low drag type of bullets are adopting G7. It is important to remember that the ballistic coefficient of any bullet is measured with reference to a particular G-function. In other words, a ballistic coefficient measured with reference to G1 cannot be used with G7, and vice versa.

CHAPTER 5

“Range and Wind Estimation”

Accurately estimating the range and wind to the best of the shooters ability in precision shooting, will give the shooter a higher percentage of hitting the target with the first round at extended ranges. Understand that ranging a target and determining the wind is nothing more than a highly educated guess. With the technology that precision shooters possess today, finding the range to a target is more accurate/precise. The wind poses the biggest problem. The effect that the wind has on a bullet increases with the range. This is mainly due to the slowing of the rounds velocity and flight time. Let’s take a look at range and wind estimation in more detail.

Range

When the shooter does not have the means of ranging a target using a Laser Range Finder, which may be due to an obstructed line of sight, batteries, or weather conditions, the shooter must be able to accurately judge the distance to the target in order to properly compensate for bullet drop.

When ranging a target, the shooter must know that certain factors affect your ability to range the target properly. These factors are nature of the target, nature of the terrain, and lighting conditions.

Nature of the Target:

-An object: A partially exposed target will appear to be more distant than it really is.

-A target that contrast with its background appears to be closer than it actually is.

-An object that has an irregular shape, such as a tree line, seems further away than an object of a regular shape, such as a human, or a car.

Nature of Terrain:

Looking over a smooth terrain, such as sand, snow, or water, you may find yourself overestimating the range to target.

Your eyes will tend to follow the contour of the terrain with the end result of overestimating as well.

Shooting targets that are in a downward angle, targets will appear to be further away while targets that are at an upward angle, will appear to be closer than they are.

Light Conditions:

The clearer the target appears to you, the closer the target will appear. If the sun is behind the target, the target will be more difficult to see, thus causing you to overestimate the distance as well. When the sun is behind you, the target will appear closer than it actually is.

Various Range Estimation Methods/Calculations

Appearance Method: when using this method, you are simply taking your desired target of interest, and looking at its characteristics, such as size, details, and overall appearance to determine the distance. In order for this method to work with some degree of accuracy, you need to know the object to some depth, such as a car, truck or house. This method is only accurate to approximately 350-400 yards.

Bracketing Method: Using this method, you are simply saying to yourself, “the target is not quit 300 yards, but more than 200 yards.” The average between the two will be your “try-distance”, or the approximate range to the target.

MIL-Relation Formulas:

(Milliradian-Based Reticle)

- Distance to Target (Yards) = Height of Target (Yards) x 1000 divided by Target Size (mils)
- Distance to Target (Yards) = Height of Target (Inches) x 27.77 divided by Target Size (mils)

- Distance to Target (Meters) = Height of Target (Inches) x 25.4 divided by Target Size(mils)

- Distance to Target (Meters) = Height of Target (cm) x 10 divided by Target Size (mils)

- Distance to Target (Meters) = Height of Target (Meters) x 1000 divided by Target Size (mils)

(MOA Based Reticle)

- Distance to Target (Yards) = Height of Target (inches) x 95.5 divided by Target Size (MOA)

- Distance to Target (Meters) = Height of Target (Meters) x 3438 divided by Target Size (MOA)

- Distance to Target (Meters) = Height of Target (cm) x 34.38 divided by Target Size (MOA)

- Distance to Target (Meters) = Height of Target (Inches) x 87.3 divided by Target Size (MOA)

Wind

For precision shooters, wind may pose one of the biggest problems. Being able to judge the wind accurately is what separates a good shooter, from an exceptional shooter. There are various ways a shooter can go about judging and reading wind, but you must also understand that being able to shoot exceptional in wind, simply takes tons of practice. We will discuss multiple methods to go about reading wind, as well as see how these methods are simply more than a highly educated guess. Please note that these wind formulas and methods have been around for some time, and have been tested and proven to work, but only to a certain “degree” of accuracy.

How do I estimate the wind?

With technology continuing to grow and expand in the shooting community, we have the means of using various instruments that read wind, such as the Kestrel wind meter. The Kestrel measures the wind speed by the movement of mechanism. A propeller is attached to a wind vane. As the wind turns the propeller within the device, an accurate wind speed is determined.

When the shooter does not have the ability to always use an electronic device, what does the shooter do? There are a few methods that you can use to determine wind velocity.

The "Hand Held" Method:

- The hand held method may be used when the shooter is not so much concerned with cover/concealment. This method requires the shooter to hold a piece of paper, grass, or some other light material at shoulder level, and then drop it. At this point the shooter will point directly at the spot where it lands and divide the angle between his/her body and arm by a constant of 4. This will give the shooter an approximate wind velocity in M.P.H.

- If this method is not available to the shooter, the next two methods are preferred.

Mirage:

A mirage is a reflection of the heat through layers of air at different temperatures and density as seen on a warm day. Mirage is seen by using a telescopic sight (spotting scope). With the scope, the shooter can see a mirage as long as there is a difference in the ground and air temperatures. In order to read mirage through a scope, you must focus on an object at midrange, then place the scope power back onto the target without readjusting the focus. Another method used is to focus on the target, then back off the focus one-quarter turn counterclockwise. This makes the target appear to be fuzzy, but the mirage will be clear.

The mirage looks somewhat like a steam, or water moving through the air and moves with the velocity of the wind. The mirage presents its wind speed by moving in lateral motions, except for when there is little wind present, or a wind that is constantly changing direction. This mirage appears to be "boiling" upward with no lateral movement. For example, a

shooter sees that the mirage is moving from the 3 o'clock position to the 9 o'clock position and suddenly changes direction; the mirage will then present a boil. The inexperienced shooter will shoot in this boil with a no value wind, thinking that the wind has died. As the shooter fires, the mirage moves laterally from the 9 o'clock to 3 o'clock, suddenly changing direction, causing the shot to miss to the right. Be careful when shooting in a boil, it could indicate a wind change, or a fishtailing wind. Reading mirage, the shooter may be able to predict the wind with a high degree of accuracy in winds up to 12 M.P.H., beyond this speed, the movement of the mirage is too fast to detect any minor change. Figure 3-21, indicates types of mirages with wind velocity.

A 3-5 MPH mirage will cause the mirage to slightly sway at angles

A 5-6 MPH wind will cause the mirage to tip at 45 degrees

A 8-12 MPH wind will cause the mirage to flat line

See Mirage diagram on next page

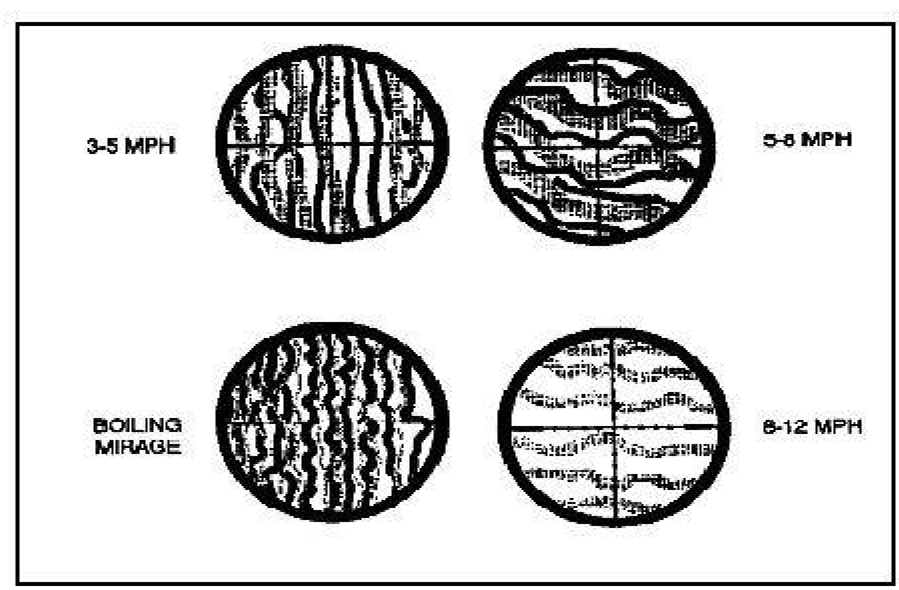


Figure 3-21. Types of mirages.

Felt Method:

This method can be helpful as well and is used by feeling the wind on your body, and visually observing the behavior of objects around you to determine wind velocity. The felt method is to be used when neither of the previous methods can be used, or to compare this method with a previous to better understand wind estimation.

-A wind that you can barely be felt on your face, or a large leaf or stem moves, you can estimate a 3-5 MPH wind.

- A 5-8 MPH wind will cause the leaves in trees to sway at a constant motion.

- A 12-15 MPH wind causes small trees to begin to sway.

Or:

-1 - 3 mph	Smoke drifts with air, weather vanes inactive
-4 - 7 mph	Weather vanes active, wind felt on face, leaves rustle
-8 - 12 mph	Leaves & small twigs move, light flags extend
-13 - 18 mph	Small branches sway, dust & loose paper blows about
-19 - 24 mph	Small trees sway, waves break on inland waters
-25 - 31 mph	Large branches sway, umbrellas difficult to use
-32 - 38 mph	Whole trees sway, difficult to walk against wind

Now having a small grasp on wind estimation, the question presents itself, “where do I judge the wind?”

As stated earlier, these wind estimation methods encounter the same problem. These methods only give the shooter a highly educated or exact (using an electronic device) wind velocity at the shooters exact position. Even with the utilization of the Kestrel, the shooter will notice that the wind speed indicated on the LCD screen is constantly changing. Determining the wind velocity downrange and at target will be nothing more than a guess, though through practice, this guess becomes more accurate.

So where should I account for wind…at my position, midrange, or at the target? This has been a big question among shooters for some time. Though no answer is wrong, through my experience, I have seen that the bullet is most affected at the shooters position, and all winds from the shooter to the target should be accounted for. For example: if there is a wind at the shooters position, and his target is 1100 yards away, the wind immediately takes effect on the bullet at his position, immediately effecting the bullet laterally. Even if the bullet was pushed left or right by ¼ of an inch at the shooters position, and the wind stayed consistent to the target, the lateral shift left or right would continue to expand just as the distance.

Some shooters would argue that the midrange wind has a greater effect on the bullet as it travels downrange. The problem that many long range and precision shooters often forget, is that the bullet does not "live" on a flat line as it flies. Meaning, when the rifle is fired and the bullet is traveling through the air, the bullet must arc to compensate for the bullet drop. The maximum ordinance (the highest point at which the bullet will reach in its flight) of a 175 grain .308 at 1000 yards is 14-16 feet above the bore of the rifle. Knowing that the bullet will have to live in a space that is 14-16 feet above the bore, the wind that you see on ground will typically not be the same at this altitude. To better understand this, imagine yourself standing on the ground and the wind speed is barely felt. Now you move onto a tower that stands 16ft. in the air. You will notice that the wind speed has changed dramatically. Your rifle bullet will feel the same wind. So by reading the mirage, or grass at ground level mid-range to target, you are almost doing your bullet injustice by neglecting the fact that the bullet will not "live" in that space.

In all, the shooter must consider all winds and the only wind we can positively determine is the wind at our immediate position, anything else will be a highly educated guess. The wind call/hold that we determine at our position should be a strong base as to what the wind hold will be. After we factor in how the wind may move in various terrain features, we can adjust our wind hold accordingly which we will discuss shortly.

Wind Direction and Holds:

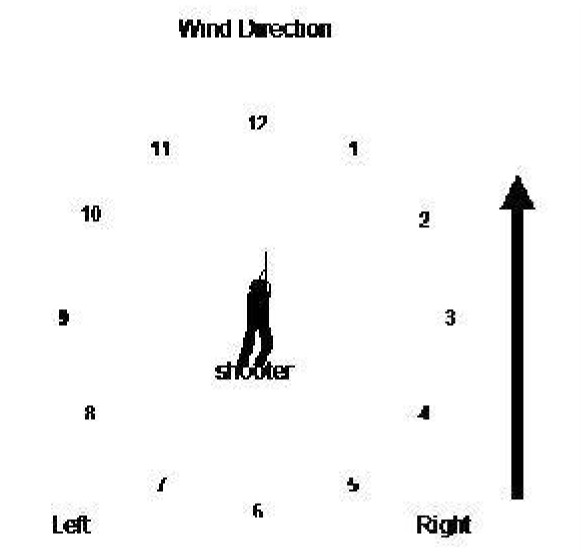
In order to accurately shoot in windy conditions, one must be able to determine not only the wind direction, but the angle as which the wind flows across the bullet in order to determine the amount of drift. A tail wind from the 6 o'clock or 12 o'clock will have a no value wind hold, they basically have no effect on the bullets flight. A direct cross wind coming from the 3 o'clock or 9 o'clock (90 degrees) into the bullets flight is known as a full value wind.

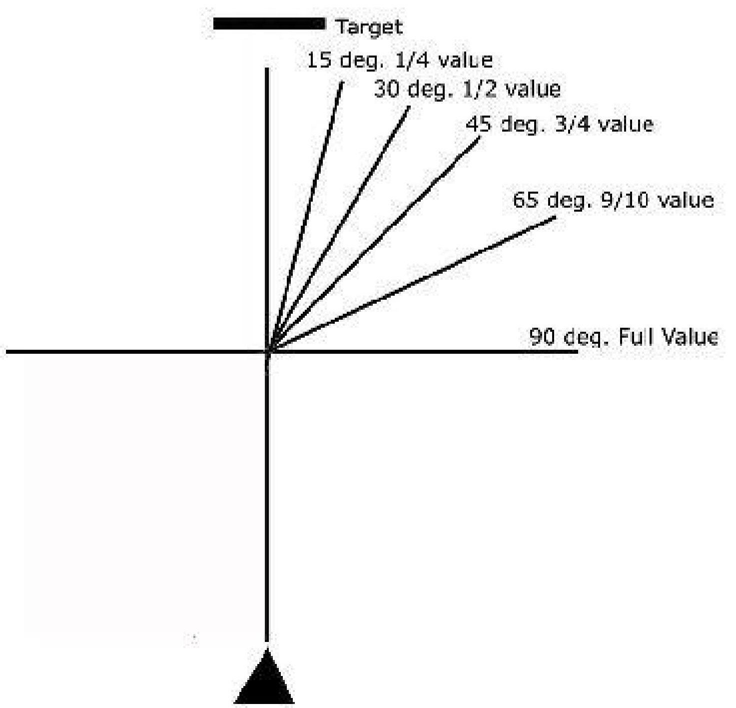
An oblique wind coming from a 45 degree angle onto the bullets flight from the right or left, is often incorrectly called a Half value wind, when in fact it is a three quarters wind value. It will have a 75 percent effect on the bullets flight to target, even though the angle of the wind call is halfway between a no effect wind and a full effect wind. This effect, and often miss-judged wind has to do with the aerodynamics of the bullet and is not exactly proportional to the "clock" system.

In order to shoot in any wind, the shooter must "shoot the bullet into the wind", using the wind to direct the bullet into the target. In order for us to do this accurately, we must use the wind holds and MOA adjustments we derived using the methods described previously. The tables listed below, have a wind value of 10 MPH, as I believe the 10 MPH is the easiest to equate, and give you a strong baseline to work from. Almost anything can be multiplied when the factor of 10 is in the equation.

Using the diagrams 3-22 and 3-23, you will be able to break down the direction of the wind as it blows to the bore/muzzle of your rifle. You then must take your MPH wind velocity and divide it by the degree value listed in diagram 3-23, to get your MOA or MIL hold.

** Wind diagram, and the wind values below:**





Wind Estimation/Formulas:

Please note that these formulas for wind only account for a "perfect world" wind shooting scenario. A perfect world wind, is described as a wind that is consistent throughout the bullets travel on a straight line trajectory to target. Being that the formulas only account for a steady wind

from the shooter to the target, one must note that this is only a strong baseline formula as to what MOA or Mil-Hold adjustment the shooter must apply to a shot. Remember that the bullet does not travel in a straight line trajectory, it has an arc that travels anywhere from one inch to 20+ feet above the barrel of the rifle…a wind velocity that varies from the ground level wind that we estimate.

Range (Hundreds) divided by 100 x Velocity (MPH) divided by the CONSTANT = Minutes of Angle Adjustment

Constants: (yds.)

100 – 500: **15**

600: **14**

700 – 800: **13**

900: **12**

1000: **11**

*** In order to change the MOA adjustment to a MIL hold, simply divide your answer by 3.43***

Range to Target divided by 100 x wind speed (MPH) divided by Constant = Wind Hold Formula in Mils

Constants:

0-500 yards: **45**

600: **43**

700: **41**

800: **39**

900: **38**

1000: **37**

USMC Wind Adjustment Method

For those of you having a boundless desire for more information, I’ve included an old U.S. Marine Corps method for computing sight changes when firing in the wind. The USMC has been using this windage adjustment method since the days of the 1903-A3 Springfield.

After determining wind direction and speed, use the following formula:

Range in 100 Yds. x Speed in MPH/15 (math constant)= MOA Windage

For instance, your target is 300 yards away, and there’s a 10 MPH wind:

3 x 10 = 30/15 = 2 MOA

Click-in the two minutes of angle in the direction of the wind and aim dead-on. This is a great formula–except it’s only accurate at 500 yards or less. When your target is farther, the mathematical constant must increase, as shown below:

600 Yards: Divide by **14**

700 Yards: Divide by **13**

800 Yards: Divide by **13**

900 Yards: Divide by **12**

1,000 Yards: Divide by **11**

Varying Wind Conditions?

When talking about “varying wind conditions”, we are talking about, shifting winds (left to right), urban environment winds, mountainous wind conditions, and open terrain. While we have formulas for a wind that moves only in one direction, all the way to the target, what will we do for winds of varying speeds at multiple points through the duration of the bullets flight? We will discuss this in a later chapter.

CHAPTER 6

“Problems With Ballistic Programs/Software”

For those of us who have used ballistic program software, we notice that the data being presented to us, will not always match precisely to the data/DOPE that we are shooting on the range. There are a plethora of reasons why our ballistic software will not match to what we are seeing downrange, we will discuss some of the most popular and how to go about correcting them.

Range:

For the shooters using a laser range finder at long ranges, let’s use 1000 yards for an example. Most manufacturers claim that their LRF’s are capable of +/- 0.5 to 1.0 % accuracy beyond 800-900 yards. This being the case, at 1000 yards, a typical .308 (168-175 gr.) will have a range error of 20 yards. 20 yards will cause an elevation error of approximately 18 inches, which equates to 0.5 mils or just about 2 MOA. Knowing that some LRF’s can produce a +/- 0.5 or 1.0 % accuracy, we can see that 1.0% error at 1000 yards is 10 yards, and not equate to what your range data may be.

Un-calibrated Scope clicks:

While taking a look at different types of scopes, I have seen that some measure closer to 1” per 100 yards than the stated 1 MOA on the adjustment knobs. Using a 168 gr. .308 round at 1000 yards, a difference in point of impact is about 20 inches.

Variation in Muzzle velocity:

A change in muzzle velocity is normal. A really good load/lot, will typically have a deviation of 15 fps above and below the quoted, or average (2650fps). This deviation of muzzle velocity will be extorted over longer ranges.

Powder temperature:

A good load, for example a Sierra Match King 175gr. .308, will show a variation of 1 foot per second per Fahrenheit degree. If your ammo is chronographed at 85 degrees, and you shot the ammo at 55 degrees, you muzzle velocity may show a 30 fps decrease. The only way to figure out what the variations of temperature will exhibit, is to simply go out and shoot it.

Ballistic Coefficient variations:

Most precision shooters use the hollow tip boat tail ammo (HTBT). The way most manufacturers publish the ammo they produce, relates to the BC in the G1 form. The G1 coefficient does not match well with the shape of the HTBT. In order for them to get around this, some manufacturers started to publish the BC in the G7 form, which will give you a better calculation of bullet velocity at range, especially for precision shooters operating in the transonic range. The problem with some ballistic software is that they do not give you the choice of inputting various BC data. Try and look for software that allows you to input a G7 BC.

Zero errors:

When zeroing your weapon, please note that if your zero is not truly "zeroed" at 100 yards, let's say off by a quarter of an inch, then your shot at 1000 yards will be off by at least 2.5 inches. This improper zero will cause your ballistic software to be inaccurate.

CHAPTER 7

“The Transonic Issue”

To properly understand the transonic problem, we need to understand the different phases of flight speeds the bullets must travel through.

When the bullet leaves the muzzle of the rifle, the muzzle velocity approaches supersonic speeds. Supersonic speed is a rate of travel of an object/bullet that exceeds the speed of sound, as we all know is Mach 1. The speed of sound is approximately 768 MPH or 1,125 FPS when the air temperature is 68 degrees Fahrenheit and measured at sea level. Any speed that exceeds Mach5 (5 times faster than the speed of sound) is considered to be hypersonic.

When the velocity of the rifle bullet reaches the region of transonic, the center of pressure (CP) shifts forwards as the bullet decelerates. This shift directly affects the dynamics of the bullet, thus causing it to become unstable. If the bullet is not stabilized, it will remain pointing forward through the transonic region, causing it to fly into an uncontrollable tumble along the length axis. This immediate shift in the CP, will cause the bullets dynamic to decrease significantly, causing it to fly erratically, in which the accuracy will decay.

The transition from the supersonic flight into the transonic flight makes an accurate/precise shot very difficult to predict, let alone calculate. Being on multiple long distance shooting ranges, I found that when using a 168 gr. .308 round, the transition usually occurs around 938 yards, making the 1000 yard shot on 14 inch steel plates very difficult (less than 5% hit rate). This is why when shooting long distances where the bullet may enter a transonic state, we look at the ambient air density. The ambient air density/DA, has a significant role on the bullet as to whether it will reach transonic before impacting the target, and has a direct effect on the bullets stability. Sever transitions into the transonic region can be negotiated by simply factoring the DA. A bullet will travel better through less dense air than when it travels through dense air.

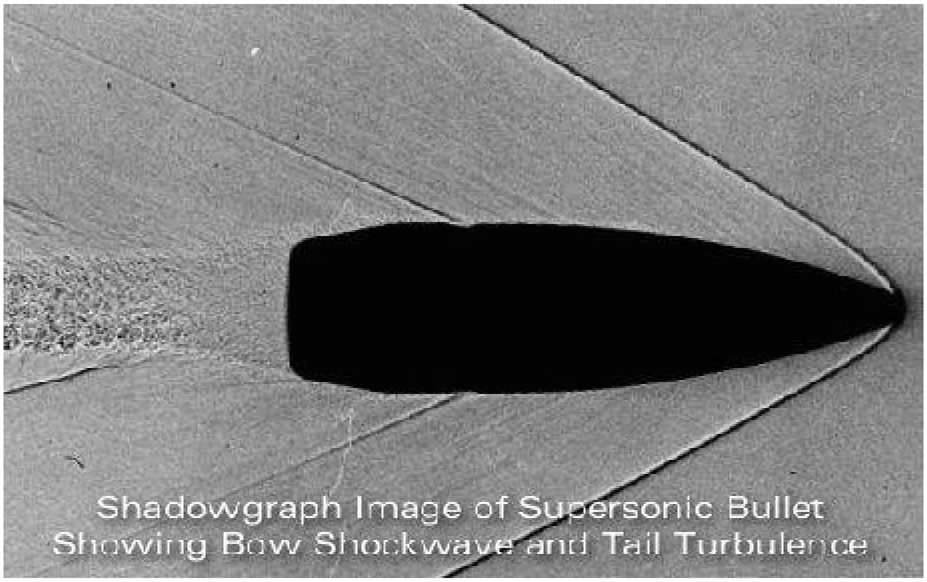
When negotiating targets that may enter the transonic region, be sure to take into effect the DA, along with your actual altitude, BP, temperature, etc.

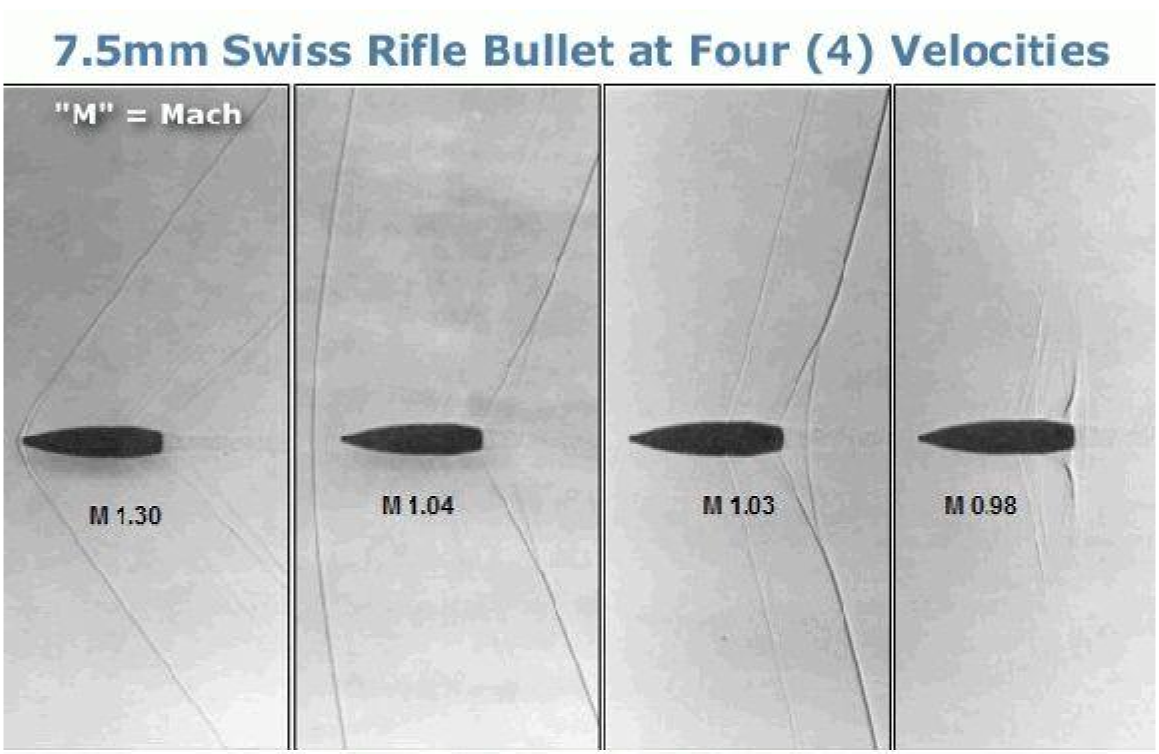
Transonic Bullet Accuracy and Stability

For those of us that shoot rifle loads (.308) that tends to transition into the transonic region around 900+ yards, we may often wonder how predictable and accurately can we make a shot at 1000 yards in this stage of flight.

Those who state that transonic bullet flight is predictable or calculable can be argued from sun up to sun down. Sure a bullet can hit a target while it's in its transonic flight, but with what hit percentage, and is it worth taking that shot with such a low hit probability? There is no simple answer as to how a bullet will perform in transonic speeds in regards to accuracy. Some bullets will perform okay, while some will perform terribly.

On the next page are a few pictures that show a bullet in various regions of flight. ***Take note to the air flow around the bullet as it passes through the different regions of flight, and how it becomes less stable.***


Shadowgraph Image of Supersonic Bullet
Showing Bow Shockwave and Tail Turbulence


7.5mm Swiss Rifle Bullet at Four (4) Velocities
"M" = Mach
M 1.30
M 1.04
M 1.03
M 0.98

CHAPTER 8

“Danger Space”

Danger space (DS) is a term not often used in the precision shooting community but should be addressed. Danger space is a point along the trajectory of the bullet, in which it does not rise above or fall below the “kill zone” of the intended target. DS basically equates to the range error that is affordable when estimating range to the target and whether the bullet will impact higher or lower the intended point of aim depending on the targets distance. The DS definition can also be somewhat confusing as well due to the fact that it does not take into consideration that a bullets flight does not travel along a single line of trajectory.

Danger space is extremely important when estimating/determining the range to a target. For example, if you range/estimate a target to be 700 meters away, when in fact the target is at 650 meters, shooting with a 700 meter D.O.P.E. on the rifle, you will completely miss the target (over the targets head).

DS grows smaller as the range between the shooter and the target increases, and allows you some degree of error when range estimating.

CHAPTER 9

“Hit Probabilities”

As precision shooters, we understand that not every shot we make will hit a target on the first round. This may be due to human error, varying environmentals, ammunition, etc. The probability of hits being made on a target out of a given number of projectiles directed at the target is known as “hit probability”.

While serving in the special operations community, the U.S. Special Operations Command (SOCOM) sponsored an effort to study various sniper weapons systems and determine what the hit probability of shooters would be at extended ranges. The study of a first round hit probability is shown as the probability of kill (Pk).

These studies were tested using multiple methods to get the best results. These methods were:

Baseline System:

This system is representative of the way a current precision rifle team/sniper team (two man team) consisting of a shooter and a spotter. The two person team using “fire control” by manually adjusting the elevation and azimuth, based on estimates of range, wind, and other effects that the shooter or spotter feel are necessary for their shooting situation. The equipment provided in this system consisted of a 10 power scope, and a 20 power spotting scope. The system also used a mini eye safe laser range finder. The crosswind was estimated by the spotter, while the ballistics portion was obtained by data of previous engagements (D.O.P.E.) from the shooter.

Crosswind Sensor system:

The second system used in this study used a crosswind sensor, which augments the baseline system providing a spotter scope that will incorporate both a more accurate LRF and down range crosswind sensor. This device will use laser technology to ensure that the crosswind is read properly. The spotter then calls the wind correction to the shooter in which the shooter will manually make adjustments.

Fire Control System:

The third and most sophisticated fire control system is referred to as "fire control." This system is comprised of the appropriate equipment required to perform a real-time, full ballistic firing solution for the sniper. Readings from the same accurate laser range finder and crosswind sensor used in the crosswind system are input directly into a ballistic computer. Sensors account for other meteorological effects such as air temperature and air density. Inertial sensors measure and compensate for weapon motion, providing the shooter with a stabilized reticle. In addition, a real-time, corrected aim point is presented to the shooter. The shooter fires the weapon by bringing the inertial and corrected aim points into convergence.

Some of the variables that were introduced while covering the test were as follows:

Ranging:

Ranging error will result in a variable bias of the shot or shot group in the vertical direction. It is assumed that the baseline weapon system includes a MELIOS-type laser range finder operated on a tripod by a trained spotter in a prone position. The targets are of sufficient size to allow placement of a 1-mil-diameter aiming circle on them. The spotter's aiming skills and stable position ensure the laser return is coming from the target and not from surrounding or intervening features. Based on field test, even during such benign conditions, ranging errors with such a range finder are between 3.4% and 9.3% of distance, not the oft-reported 5-m intrinsic accuracy of the MELIOS.[31, 32] A value of 5% of distance is arbitrarily used because it is about midway between the field data. In addition, MELIOS only displays range in 5-m increments. For the 100-m range values for which error estimations were computed, 5% yields 5-m increments. The crosswind sensor and fire control weapon systems include an improved range finder as part of the crosswind sensor. A stated range accuracy by one of the crosswind sensor developers is 1 m.[28] Also, work done under the objective individual combat weapon has resulted in a laser range finder that works through clutter. For this study, the target is assumed to be stationary, so there is no random shot-to-shot ranging error.

Round Dispersion:

Round or ammunition dispersion is what the bullets might be expected to do during the most ideal conditions, i.e., from a machine rest barrel, known range to target, zero pointing error, no wind, etc. Since no two projectiles of the same type are exactly alike because of tolerance differences, launch cycles, and other factors, no two rounds will follow the exact same trajectory. The amount of error varies from ammunition type to ammunition type and even between lots for one ammunition. Dispersion estimates are universally based on ammunition acceptance test data often at short ranges (e.g., 100yd). Limitations in the instrumentation and procedures thereof may account for a certain portion of dispersion error.

Weapon Pointing (aiming) Error:

Weapon pointing error is the ability of a shooter to hold his or her aim on target. Any skilled sniper would claim that his or her weapon pointing error is zero. All misses arise from a cold barrel, a gust of wind, or some other vagary.

Weapon Cant:

Errors are introduced into the elevation and deflection calculations when the weapon is canted or rolled about its lengthwise axis because of uneven weapon emplacement. The baseline and crosswind sensor weapon systems rely on the shooter to level the weapon. Nevertheless, it is assumed that a trained sniper takes great care to emplace his or her weapon. When emplaced for the firing mission, the weapon is assumed to be level to within 1° standard deviation from the last time it was emplaced. During the firing mission, the cant is assumed to randomly vary no more than 1/10 of a degree from the value at which it was emplaced. For the fire control system, inertial sensors on the weapon will correct for cant.

Sight Resolution:

Because human operators, optical sights, and electro-optical devices are not perfect, a factor is included in Reference 33 to account for the limits encountered in resolving images. The value used by Reference 33 (0.06 mil) is used for the baseline and crosswind sensor systems. Although this is a relatively small part of the error budget that could be considered a part of weapon pointing error, it was included to make the following distinction between systems. The inertial reticle technology, proposed as a key portion of the fire control, allows a 3 Ox magnification of the target versus lOx

from a regular scope. Thus, the sight resolution error for the fire control system is set to be one third of the baseline, 0.02 mil.

Optical Path Bending:

When viewed from a shooting position, the effects of atmospheric shimmer may cause a target to appear displaced from its actual location and possibly to seem to be moving when it is not. The effect can be greatly amplified by high temperatures and terrain reflectivity. The value used in Reference 33 is used here (0.00003 mil/m). Although video processing techniques that reportedly correct for this effect have been developed, they are not proposed as part of the fire control, and the system will not compensate for optical path bending.

Zeroing:

At some time before the mission, the system will be calibrated through a live firing exercise. When a weapon is zeroed, the center of impact of a group of rounds is moved to the center of aim by adjusting the sight/weapon offset. Because a small number of rounds, typically fired during zeroing, cannot exactly determine the center of impact for all groups and to the extent that firing conditions such as wind, temperature, muzzle velocity, etc., are not perfectly known at zeroing, the procedure itself introduces an error. This is a variable bias error, not a random error.

Knowing all of the variables and methods of shooting used in this experiment, let us take a look at the results of hit probability (PH*) below. The PH* are shown with multiple weapons systems and ammunition:

The targets used in this experiment were an E-Type 40x20” silhouette, and with varying winds which were determined using the methods listed above.

.300 WM (190 grains, 2900 fps muzzle velocity)

Range (m):	PH* (averaged between CW sensor Baseline):
100	1.00
200	1.00

300	0.97
400	0.80
500	0.63
600	0.435
700	0.39
800	0.20
900	0.135
1000	0.112
1100	0.045
1200	0.03
1300	0.02
1400	0.015
1500	0.01

Knight SSW SR-25 M118LR (175 grains, 2600 fps muzzle velocity)

Range (m):	PH* (averaged between CW sensor Baseline):
100	1.00
200	1.00
300	0.96
400	0.775
500	0.555
600	0.375
700	0.245
800	0.16

900	0.105
1000	0.065
1100	0.036
1200	0.02
1300	0.021
1400	0.002
1500	0.001

.338-.416 Sierra MK (300 grains, 3040 fps muzzle velocity)

Range (m):	PH* (averaged between CW sensor Baseline):
100	1.00
200	1.00
300	1.00
400	0.97
500	0.855
600	0.695
700	0.53
800	0.52
900	0.50
1000	0.45
1100	0.35
1200	0.95
1300	0.65
1400	0.45

1500	0.25

CHAPTER 10

“Understanding Precision High Angle”

Precision high angle shooting is an art form in its own. High angle shooting is described as when the gun is sighted in (zeroed) on a level or nearly level range, and then the rifle is fired either in an up-hill or down-hill direction, such as fired from a mountain top, or tall building onto a target below, or vice versa. This effect is common to precision shooters, especially with Law Enforcement, hunters, and military snipers. Through understanding high angle, we know that the bullet will always impact high. How high the bullet will impact high is determined through precise calculations using mathematical formulas.

Exactly knowing high the bullet will impact we need to revisit “bullet drop” and the “bullet path”. Bullet drop is always measured in a vertical direction regardless of the elevation angle of the bullet trajectory. The bullet drop is expressed as a negative number as the bullet falls away/below the bore line.

The bullet path is measured always in the perpendicular to the shooters line of sight through the sights on the gun. It would be where the shooter would visually “see” the bullet pass at any instant of time while looking through the sights of the rifle, if this was even possible. At the rifles muzzle, the bullet path is negative because the bullet starts out below the line of sight of the shooter. Near the muzzle, the bullet will follow a path that will rise and cross the line of sight, then the bullet will travel above the line of sight until the target is reached. The bullet path is expressed as positive in this portion of the trajectory/flight. The bullet arc then crosses the line of sight at the zero range, meaning the bullet path is zero at the zero range, and will become a negative as the distance increases past zero range.

Do not let high angle shooting start to confuse you, we can look at it in a very basic sense. As human beings, we have all had a chance to throw an object at a distance, may it be a rock, softball, etc. Let’s say you are tossing a rock in an underhand fashion at an object 20 yards away on a flat plain. Through your years of experience of rock throwing, you will naturally throw the rock high to create an arc to compensate for gravity in order for it to reach the target. Now let’s look at the situation, except that the target is

on a downhill slope. The ground distance is still 20 yards away, but your 3 stories up on a rooftop. The same arc above the line of sight that allowed your rock to hit the target at ground level, on the flat plain, if applied to the uphill position, will now cause the rock to travel over the target.

The same rule applies to shooting high angle. When zeroing your rifle at a flat plain, the bullet must create an arc, while shooting at high angle, the arc is slightly different. The effect of this error increases with distance and steepness of an angle to a maximum of 60 degrees. This error applies to both uphill and downhill shooting, meaning that the bullet will always hit above the target, thus you must hold/dial lower than the actual distance to the target.

***** The more the angle….the less effect gravity has on the bullet/Shorter gravity distance. *****

The mathematics behind figuring out exactly how low we need to hold/dial on the scope is determined by using the Pythagorean Theorem. In mathematics, the Pythagorean Theorem is an equation that is expressed as, $A^2+B^2=C^2$ and is relating to the lengths of the sides a, b, and c. For our purposes, the “a” and “b” will represent actual heights/lengths, and “c” is what we need to figure out, also known as the “slope dope”.

For faster target engagement, we can use another formula that I found to be easier to understand and equate. The equation is simply “actual straight line distance multiplied by the cosine of the angle = slope/corrected distance.” There are many ways to find the cosine of an angle when shooting, but the simplest way that I found to obtain this information, is using a “ Angle Cosine Indicator”. An angle cosine indicator simply takes your angle to target (uphill/downhill) and presents you with the cosine of that angle. Once this number is inputted in the equation, you have the data for a shot “corrected for gravity” for a high angle shot. They can typically cost anywhere in the range of $65.00 – 150.00, for a civilian model.

(Below is an A.C.I. (Angle Cosine Indicator)).

Let's take a look at an example and how to properly apply the A.C.I.

You shooting off of a mountain top at a target that you laser range find at a distance of 950 yards. Being that the angle to your target from on the mountain is so steep; you look down at your A.C.I. and see that the red line is at the number 77. Now what? You simply take your actual distance to target and multiply it by .77. So, 950 yards multiplied by .77 = 731.50 (732 yards) a 218 yard difference, thus causing a miss. The 732 yards is what your corrected elevation is. You then dial in for a 732 yard shot instead of a 950 yard shot.

Sure there are various ways to find the cosine of your angle to target; I simply find this one of the most practical ways, besides the MIL dot Master, or Slope Doper.

Below are a few tables that you can also use by simply imputing your ballistic bullet drop data. To find up/down compensation, take the Bullet Drop data (which is stated in hundreds of yards) and multiple it by the factors in the accompanying chart, based upon the steepness of angle to your target. For example, your target is 400 yards away, uphill 45 degrees, and you're firing a .223 Remington, 69-gr. Match round. You already have the data that your Bullet Drop is 36.3 inches at 400 yards. Therefore, you multiply the 36.3 Bullet Drop inches by .293 and find you must hold low 10.63 inches for a perfect hit.

UP / DOWN COMPENSATION FACTORS

5 Degrees: Drop Inches x .004

10 Degrees: Drop Inches x .015

15 Degrees: Drop Inches x .034

20 Degrees: Drop Inches x .060

25 Degrees: Drop Inches x .094

30 Degrees: Drop Inches x .134

35 Degrees: Drop Inches x .181

40 Degrees: Drop Inches x .235

45 Degrees: Drop Inches x .293

50 Degrees: Drop Inches x .357

55 Degrees: Drop Inches x .426

60 Degrees: Drop Inches x .500

With much credit given to the F.B.I. and A.T.F. snipers that I have worked with, they introduced a pretty fast method for angle shooting. Here's how the method works:

You range a target at 500 yards and your slope/angle to target is 30 degrees up or down. You would simply shoot it as if the target is on a flat ground distance, at 90 percent of that distance. This means, service the target as if it were at 450 yards. You can do this by simply holding under for a 450 yard shot, or dial it on the scope elevation knob.

****** Basically they have stated that you should engage any 30 degree target (uphill or downhill as if it were 90 percent of its actual distance), well within the danger space. ******

When shooting a .308 168 grain Match ammo, this method typically has a maximum error of 4 inches at 610 yards, with an average of less than 2 inches at ranges less than 600.

The next method that we have used and tried, is the 45 degree method. Basically put, you would shoot a target at a 45 degree angle as you would on a flat plain, except you would engage it with only 70 percent of its actual distance. Meaning: a target that has a flat line distance of 500, 70 percent of that distance would be 350 yards. Your corrected elevation would be 350 yards instead of 500. ****** Engage any 45 degree target as if it were 70 percent of its actual distance.******

Out to 600 yards, firing .308 Winchester 168 gr. Match ammo, using 70 percent of the distance, the maximum error is 4 inches, with an average error of less than 3 inches.

* Please note that this chapter is to only get a firm grasp on high angle shooting.*

CHAPTER 11

“Common Precision rifle Theories & Errors”

Theories in precision shooting can run on throughout this instructional book. We will only discus the most common theories in precision shooting, but not to “disprove” them, but to better understand how they will affect our way of shooting.

I’m sure all of us have watched movies, read multiple sniper manuals, and attended sniper course that address, do’s and don’ts, as well as “these things will affect your bullet at long range” theories. Any precision shooter should only take these statements with a grain of salt. Throughout my years of precision shooting, in combat, completion, and multiple training courses, I’ve learned that one should never take the words, “always” and “never” too seriously. Sure there are some things that you should never do and always do, such as never point your muzzle at anything unless you fully intend to destroy it, or always treat your weapon as if it were loaded. But when it comes to ballistics, when we here these key words…do we test them. More often than not, we listen to the instruction and do not test the theories of ballistics presented to us.

Let us now take a look at various theories of precision shooting and how they can/do or do not apply in our world.

Cold Bore:

A cold bore shot in the shooting community is simply defined as: the first round fired from the muzzle of the day, when the barrel has been undisturbed, cold, and barrel foiling has not interfered with the round opposed to a rifle that has been shot. The theory of the cold bore shot is that the bullet fired from a cold bore will differ from a heated barrel (more than one round through the barrel).

In the sniper schools that I have attended, a cold bore shot at any extended range in pretty impressive. Simply due to the fact you were able to properly compensate for the bullet deviation in a “cold bore”.

How does this apply to our world of precision shooting? Is it truly a “cold bore”?, and does it affect our first round impact? Below you will see

and understand my explanation of cold bore shooting, along with the physics to further explain:

If the barrel is "cold", before any bullet passes through the barrel on any given day, we assume that the round will be high and right or left of the desired point of aim. This is typically what I have seen. The first bullet of the day usually shoots high and right or left, sometimes as much as 5 MOA at 100 yards.

A barrel being a metal object, will bend under heated conditions, however high the temperature will be, metal will bend. Understanding physics, friction, and the properties of metal under heated conditions, we should assume that a barrel that is continuously fired will get hot and bend as well. If the barrel is cold at the first shot of the day, and we impact high, then as the barrel is now heated as rounds 2-5 are fired, and we impact point of aim point of impact, how does this make since through the laws of physics? After all, the hotter the metal is, the more rapidly it begins to bend.

Take a look at it in these terms. After one round being fired from a high powered rifle, we are able to still touch the barrel comfortably. But, after rounds 5-10 and fired, it can begin to burn the skin fairly quickly, and rounds 20-30, you can almost light a piece of paper on fire when touching the barrel. Knowing that the barrel heats up when multiple rounds are fired, and the barrel being a metal object, shouldn't the barrel bend, thus causing a degrade in accuracy. As we all know this is not the case when grouping ½ MOA – 1 MOA at 100 yards. Typically the shooter will place 4 out of the 5 bullets within the specifications of the rifle, the one round that got away being the cold bore.

The question is then, "what is cold bore"? I believe a cold bore shot is nothing merely than a "Cold Shooter". As humans, we weren't built to have an explosion happen six inches from our face. Knowing that this explosion is happening, as humans, our natural bodies' reaction to defeat this is to flinch. When the body flinches or tightens, it contracts the muscles within us, thus causing our body to "shrink". When the body does this, we become a smaller object in order to protect ourselves from oncoming danger. This directly affects our point of aim and point of impact. As our body shrinks/becomes slightly smaller (closer to the ground

in prone), our rifle sights will rise (as to when you let out the air in your lungs opposed to a full set of lungs) the sights of the rifle will rise.

In order to defeat this, proper dry fire takes precedence over live fire. Our brains work off of repetition, also known as muscle memory. Once you do things longs enough, your brain becomes used to that nature of operation, which we call a habit. When dry firing a rifle long enough to the point that the brain will not anticipate recoil when the trigger is pulled for the first time (because it is used to only a click), you will see that your "cold bore" shot on live fire will dissipate.

Another example used is one shooter shooting a group (5 rounds) at 100 yards. The shooter then immediately gets on a "cold rifle" that has not been shot. His cold bore round is gone. All of the next five rounds fall within the rifles specifications.

So then again….Is this a cold bore, or a cold shooter?

Follow Through:

Some believe and argue that the follow through on the trigger is not as important when it comes to fundamentals, due to the fact that whether the trigger is slapped or yanked, or simply flies off, that the bullet has already left the barrel and is now on the way to the target.

In order for us to understand the importance of follow through, we need to take a look at the step by step process the rifle must go through before the bullet exits the muzzle.

1.) The brain makes a conscious decision to pull the trigger to the rear.

2.) The finger now receives this command and begins to apply pressure, causing the pad within the finger to depress in the distal phalanx (the pad on the trigger finger that separates the tip from the first joint).

3.) Once the pad in the trigger finger is compressed, tension begins to form, exerting the prescribed trigger pull weight (typically 3-5lbs.)

4.)Once the trigger finger pad is compressed and the trigger pull weight is achieved and compressed to the rear, the trigger releases the hammer.

5.) The hammer then slams forward a prescribed distance, thus causing it to make contact with the firing pin.

6.) The firing pin then moves forward a prescribed distance, and then makes contact with the primer of the bullet cartridge.

7.) Once the primer is hit, it sparks, causing the gunpowder to burn at a rate. Not exploding!

8.) Once the powder begins to burn, pressure begins to build within the cartridge itself. As the pressure builds, it will find a path of least resistance, this being the bullet projectile being held within the cartridge.

9.) When enough pressure builds, the bullet will unseat itself and slam forward into the rifling of the barrel.

10.) As the bullet makes contact with the barrel, it begins to pick up 168,000-230,000 R.P.M.'s while moving through a 26 inch barrel.

11.) Once the bullet reaches the crown of the barrel, it will pop out similar to a Champaign cork.

Knowing all of this, is follow through important?, after all the bullet is still in the barrel! Think of it in these terms. When the trigger is pulled, and the bang of the rifle is perceived, most shooters tend to blink, and still be able to open the eyes while the sound is still being perceived. The human eye blink is calculated at 300-500 milliseconds. There are only 1,000 milliseconds in one second. So my question to you is, is proper follow through needed, meaning holding the trigger back and to the rear until the perception of recoil is over, when the bullet fully exits the barrel, or do we disturb the bullet while it is still in the barrel? I believe follow through is important!

Spin Drift/Gyroscopic drift:

Gyroscopic drift, better referred to as spin drift, has plagued precision shooter controversy for many years. Spin drift is simply defined by precision shooter as a bullet with a right hand twist, the bullets rotation will

spin to the right of the target, while a rifle with a left hand twist will rotate to the left, due to the way the air moves across the bullet as it spins through the ballistic arc on a long rage trajectory. As an effect of this small inclination, there is a continuous air stream, which tends to deflect the bullet to the right. Thus the occurrence of the yaw of repose is the reason for bullet drift to the right (for right-handed spin) or to the left (for left-handed spin). This means that the bullet is "skidding" sideways at any given moment, and thus experiencing a sideways component.

Basically, at extended ranges, a bullet will shift right or left, depending on the rotation of the bullet.

Though Spin drift is absolutely true, does this necessarily apply to the precision rifle shooter at ranges up to 1000 yards?

Some say that spin drift does apply in precision rifle shooting, in fact here are a few spin drift tables along with an equation to calculate spin drift:

Spin Drift= 1.25(Sg + 1.2)tof ^ 1.83

-Where Sg = Miller Stability formula (which can be found for your rifle load)

-Tof = Time of flight

Shooting a .308 Sierra MatchKing HPBT 175 gr. 2600 fps., Barrel length of 26" and a 1:12 twist rate). The Spin drift is as follows:

Range (yards)	Spin Drift (inches)
100	0
200	0.25
300	0.68
400	1.31
500	2.17
600	3.29
700	4.73

800	6.54
900	8.79
1000	11.57

(Chart 4 above)

After taking a look at the data in the table above, I have to ask precision shooters this question, "at 200 yards on a 2 inch dot, how many of you are able to center punch the target, without dialing for "spin drift", and only use your 100 yard zero."

Now take a look of another ballistic calculators estimate for spin drift using the same load, except starting at 300 yards:

Range (yds.)	Spin Drift (inches)
300	.5
400	.9
500	1.44
600	2.14
700	3.69
800	5.96
900	6.25
1000	7.19

(Chart 5 above)

The data for a 1000 yard shot shows an 11.57 (chart 4) inch drift due to "spin drift", which is almost the drift in inches for a 1 MPH wind: ≈1 MOA or 10 inches. Now understanding ballistics (trajectory), we know that the max ord. of a .308 round will reach ≈16 ft. above the bore of the rifle at 60% of the range to target. Now we look back to the wind chapter, we can see that a 1 MPH wind is fairly hard for us to estimate, especially when that 1MPH wind may be at a 16ft. elevation. So we ask our self, how does spin

drift affect us at 1000 yards….? In my opinion, while it does exist, it does not apply in our precision shooting world, when wind is a beast in its own. Also due to the inaccuracy of “spin drift”, it’s hard to pinpoint the effect of spin drift on a bullet at extended ranges.

My advice to any shooter experiencing spin drift , is to look back at the fundamentals chapter, apply them, and see what happens to your once before spin drift.

Coriolis Effect:

In the precision shooting community, Coriolis Effect/drift is explained as, during the bullets flight, it moves in a straight line (not counting gravitation and air resistance for now). Since the target is co-rotating with the Earth, it is in fact a moving target relative to the projectile, so in order to hit it the gun must be aimed to the point where the projectile and the target will arrive simultaneously. So in other words, you need to not shoot where the target is, but will the target will be, taking bullet flight time into consideration.

Due to the Earth’s rotation, our target will not be in the same spot from the time we fired the rifle. Let’s take a look at this mathematically:

The speed of the Earth rotation varies upon your latitudinal location on the planet. Let’s say you are standing at the North Pole, the speed is almost zero, but at the equator, where the circumference of the earth is greatest, the speed is ≈ 1,038 MPH. This seems fast, but do not forget that the Earths circumference is 40,075 km at the equator, and takes 23 hours 56 minutes and 4.091 seconds to rotate. Breaking it down even further (bullet terms): a bullet on average travels ≈2600 fps when exiting the barrel and reduces due to atmosphere drag (at 1000 yards the bullet is traveling 1,178fps = 803.1 mph). 2600 fps, is 1772.7 MPH, and the earth is traveling 1522.4 fps (continuously). We also know that on average, a bullet (.308) traveling at 2600 fps will reach a 1000 yard target in ≈ 1.7 seconds.

So now that we have some basic numbers (+/- latitudinal speeds), what will be our spin drift at 1000 yards? We can take a look at a shooter in the latitude of Sacramento; a bullet traveling 1,000 yards would be deflected ≈+/- 2 inches to the right. Knowing this we can dial this in on the scope or hold for it correct? Not the case. A .1 MIL adjustment on the windage as

we know will be ≈3.6 inches, thus overcompensating for spin drift. Knowing that, are we as humans capable of visualizing 1.89 or 2 inches at 1000 yards with our scope. If we were able to, would this correction matter on a near perfect shooting day, with 0-1MPH winds (baseline and at elevation)? Do not forget that a 1MPH wind at 1000 yards will shift a bullet left or right 9 – 10 inches.

Wikipedia does acknowledge the Coriolis, but says, “For small arms, the Coriolis Effect is generally insignificant, but for ballistic projectiles with long flight times, such as extreme long-range rifle projectiles, artillery and intercontinental ballistic missiles, it is a significant factor in calculating the trajectory.”

With all of this information that we have and now know, I believe the Coriolis to be not significant enough for us to worry about, let alone calculate or dial on our scopes.

Holding your breath makes me more stable:

Not only do some of us believe that holding your breath makes you more stable when shooting a precision rifle, this is actually in the US Army Sniper Manual FM 23-10. The manual actually states that you should hold your breath before taking a shot, but not to exceed the hold for more than five seconds.

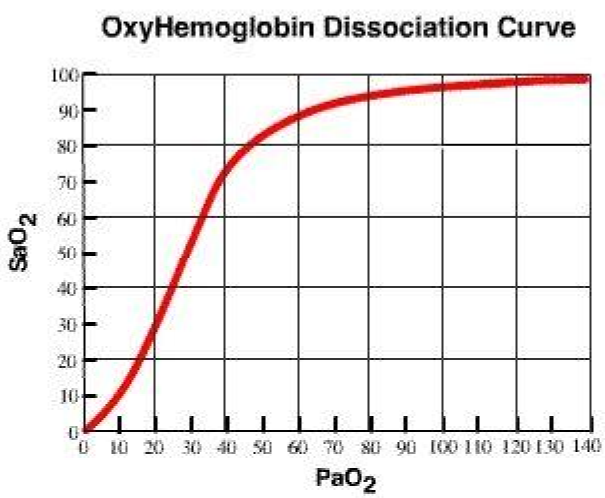
After talking to an M.D. extensively and understanding the amount of oxygen our body needs to function at its prime, we need to understand the how oxygen works within our body in relation to precision shooting. As we know by now, precision shooting has more to do with working through a problem using our brain than it does with looking through a scope and pulling the trigger. In order for us to think through a problem, break it down, and perform fundamental calculations in our brain within a short period of time, our brain needs to be operating at its highest capability. The human brain only represents 2% of the human body weight, it receives 15% of the cardiac output, 20% of total body oxygen consumption, and 25% of the total body glucose utilization.

The energy consumption for the brain to even survive is 0.1 calories per minute, while this can be as high as 1.5 calories per minute during a crossword puzzle. When performing the tasks required in precision

shooting, the brain can consume as much as 2 calories per minute, or more. When neurons in a particular region of the brain are highly active, they consume a great deal of oxygen, which results in recruitment of extra blood flow to that region.

Mental performance in the human body can simply be improved by feeding the brain with oxygen. It is well known that after about nine minutes of no oxygen, the brain with shutdown. Brain cells are extremely sensitive to oxygen deprivation and can begin to die within four to five minutes. Even though this is taken to the extreme, an oxygen crisis can begin within two seconds. Within this short amount of time without having oxygen, our body begins to express its starvation by shaking; this shaking will begin in our eyes. Even though we may not notice the shaking in our eyes, it does occur. The reason why we do not notice it, is simply because our eyes and brain will compensate this shake/flutter by giving you a steady sight picture.

To better understand and to get a visual on how oxygen/breathing can affect our precision shooting, and how fast we become less affective, we can take a look at an Oxygen Dissociation Curve Chart.



This curve describes the relationship between available oxygen (may it be altitude, or self-induced) and the amount of oxygen carried by

hemoglobin (a red protein responsible for transporting oxygen in the blood of vertebrates.)

The horizontal axis is Pa02, or the amount of oxygen available.

The vertical axis is Sa02, or the amount of hemoglobin saturated with oxygen.

Once the Pa02 reaches 60 mm Hg the curve is almost flat, indicating the individual or shooter has little change in saturation above this point. But, anything less than 60 mm Hg, the curve is very steep, and small changes in the Pa02 greatly reduce the Sa02. An individual at rest may have a Pa02 of around 85-100 mm Hg, while smokers may be in the range of around 80-85. Note that this is at rest. When we are under stress and have been performing an exercise, our Pa02 levels may drop in the 70's range. By holding our breath while within this range (4-5 seconds) our oxygen saturation can easily fall below 60, thus, dramatically decreasing the amount of oxygen we are providing to our vital organs, such as the brain.

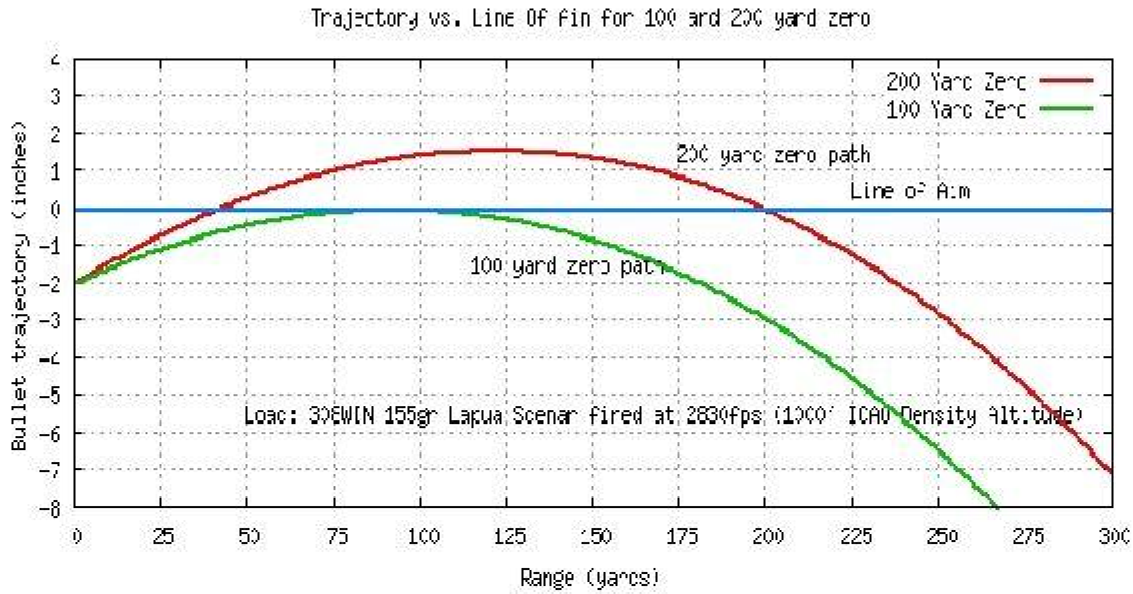
CHAPTER 12

“Mechanical Offset and Influence on the Barrel”

Not all of our shots in precision shooting have to deal with extreme distances. Some of precision shooting can occur within a few yards or within a few feet. Simple thinking to a shooter says that if you have a 100 yards zero on your rifle, and a target presents itself at 20 feet, a simple hold-under will do the trick by understanding the hold over and hold under. A target further than your zero, you must hold over to compensate for bullet drop, and a target closer than your zero, you hold under.

In the precision shooting community, we focus on only the long engagements, simply because it’s cool. Sure there is a lot of thinking involved in a long range shot, but at close ranges, to make a precision shot under some sort of pressure and time constraints, the knowledge to achieve a close range precision shot is in itself an achievement.

There are a few stories told by police snipers of targets being engaged at extremely close ranges, within 10 yards on hostage takers. In order for this sniper to achieve this shot, he had to understand something that is often not practiced in our community, which is the mechanical offset. The mechanical offset is simply defined by the distance from the bore of the rifle and the center of the rifle scope. The typical offset between the two (center of scope and the center of the bore of the rifle) is around 1.5 – 2.0 inches. For a target that is closer than 100 yards, let’s say 20 yards, we need to hold over on our target, while the bullet flight is generally flat. If we were to visualize a straight line from our barrel to a target 20 yards away, and a straight line from our scope to the target and measure the distance (1.5 inches), we can see that the line from the scope is higher than the bore of the rifle. In order for us to hit the target, we need to hold over the target the distance between the bore and scope.



Taking a look at the chart above, we can see that with a 100 yard zero, taking a shot within 75-76 yards, we need to hold over the target, as well as a shot taken beyond 110-120 yards.

Influence on the Barrel:

As many of us are told during the different shooting schools that we attend, we are told to never rest your barrel on "anything" and shoot. The question we need to ask ourselves, is, "what will happen if I rest my barrel on an object and shoot?"

We know that the rifle and barrel act as a "tuning fork" and bounces away from objects when the weapon vibrates when fired. The barrel of the rifle, being a steel object, bends. For example, if the barrel is resting on an object when fired, the impact of the bullet will impact high. Depending on whether the barrel is resting on an object or touching the sides, the bullet impact will differ. If the barrel has an influence from the left side, the impact of the bullet will be right.

The test that have been conducted show that depending on the amount of pressure the shooter places on the rifle if the barrel is resting on an object,

the impacts of the round will differ. The greater the pressure induced on the rifle, the greater the bullet impact will be influenced. Another factor to consider, is where the barrel is being influenced, nearest to the shooter, the middle, or near the muzzle.

We have also found that if the influence on the barrel is consistent, and at the same point of contact, you can actually group the rifle with the accuracy as if you were in the prone.

Please Note: the shooter should not take precision shots (5" targets) beyond 250 yards. 300 yards should be the maximum distance targets should be engaged when having an influence on the barrel and the target size is adequate.

CHAPTER 13

“Ammunition & Terminal Ballistics”

Terminal ballistics is a sub-field of ballistics, and the study of the behavior of a projectile when it hits a target. This is also referred to “stopping power” when dealing with a human or a living target.

For precision shooters who are practice this art in the hunting community, or for precision shooters who are in the Law Enforcement and Military community, this is extremely important. We need to be able to determine how much energy will be transferred to the target. The amount of energy that is transferred into the target, is important in order to determine the lethality of the round once it hits a target.

Do you know the distance at which your bullet runs out of energy to reliably kill a deer sized animal? There is a rule of thumb that most shooters judge this by. This rule is that a bullet must deliver at least 1000-ft. lbs. of energy. Aside from a proper shot placement, and bullet design, this is a relatively practical way to determine your purchase of ammo that offers you a good ft. lbs. transfer into your target.

Please note that this 1000 ft. lbs. of energy transfer, is only a rule of thumb. The bullet design, weight, and velocity paly a large role.

Below is a list of some popular rounds among the hunter, law enforcement, and military communities.

Information displayed as, (-Bullet type, Bullet weight, Bullet velocity, 1000 ft. lbs max distances).

-.223

55 gr., 3240 fps, 100yrd

60 gr., 3160 fps, 100yrd

69 gr., 2950 fps, 125yrd

77 gr., 2750 fps, 125yrd

-.243

85 gr., 3320 fps, 350yrd

95 gr., 3025 fps, 350yrd

100 gr., 2850 fps, 350yrd

-7mm

150 gr., 3100 fps, 850yrd

160 gr., 2950 fps, 750yrd

175 gr., 2760 fps, 820yrd

-.300 WinMag

150 gr., 3200 fps, 725yrd

180 gr., 2960 fps, 650yrd

190 gr., 2900 fps, 925yrd

200 gr., 2700 fps, 750yrd

-.308 Win

150 gr., 2820 fps, 600yrd

165 gr., 2700 fps, 625yrd

180 gr., 2620 fps, 775yrd

-.338 Win Mag

180gr., 2830 fps , 850yrd

200 gr., 2660 fps, 775yrd

CHAPTER 14

“Calculating Mil-dot reticle Holdovers”

So now that we have the grasp on using the Mil –dot scope and the elevation turrets, let’s now combine the two in a manner so that we can simply hold over or under a target at extended ranges, instead of dial it in on the elevation turret.

Using a hold over or hold under, simply put is when zeroing your scope, or set a zero on the elevation turret (100, 200, 300, etc.), you shoot beyond that distance or shorter than your zero distance by aiming above or below your target a specified amount using your Mil-dot scope. Realize that your scope is nothing more than a unit of measurement, or a ruler in front of your eye.

Hold overs and unders are useful because it is extremely fast, and the shooters eye never leaves the scope, opposed to reaching up and dialing in on your elevation turret for each shot at different ranges. The old-fashioned way is simply to know how high to hold at a given distance, then "hold over" that height to strike the target. For instance, a .308 rifle firing a 168-gr. boat tail match round with a 100-yard zero, would impact 35.5 inches low at 400 yards. Since the shooter knows this, he aims what he reckons to be that height (35.5 inches) over his 400-yard target, fires, and hits it.

So now understanding the benefits of Mil-dot hold overs and unders, let’s figure out how we can convert our data (trajectory) to Mil holdovers.

In order to calculate hold overs and unders, we first need to obtain the rounds trajectory. We can accomplish this by using two methods, the first being going on-line and look at the rounds trajectory path, which may or may not apply to you accurately. The second, more accurate method is to take a look at your personal D.O.P.E. and obtain your MOA come ups for your yard lines, i.e. 100 = 0 MOA, 200 = 2.0 MOA, etc.

We’re going to use the second method and use our own data to obtain the hold over and unders. Now let’s assume that we have a scope that adjust in MOA and has a Mil dot reticle. The first thing that we need to do is right down our MOA come ups with the corresponding ranges. I’ll use my data for a .308 175 gr. HPBT.

Range	MOA
100	0
200	2.0
300	4.5
400	8.0
500	11.7
600	15.5
700	20.3
800	25.5

Now having this data, we are going to use a 400 yard zero, so we put our 400 yard MOA on the scope, in this case 8.0.

In order for us to calculate the hold under for a 200 yard shot, we take our D.O.P.E. for 200 yards and subtract from it the dope we have on our rifle. After this has been accomplished, we then convert the difference to MILs by dividing it by 3.438. If the number is a negative number, then this is what we call a hold under. The positive numbers are hold overs.

Using the example above, a 400 yard zero and shooting a 200 yard target, we can see what the math looks like:

2.0 (200yrd MOA) – 8.0 (400yrd MOA) = -6

We now divide the **-6 by 3.438** and we get **-1.74**

The -1.74 is the amount of Mil dots we will hold under the target.

Now let's reach out a bit further. Say we are using our 400 yard zero (8.0), and we want to reach out and hit a target at 700 yards:

20.3 – 8.0 = 12.3 / 3.438 = 3.57

3.57 is the MIL dot hold over because the number is positive. So you would hold 3.57 ≈ 3.6 MILs over the target.

The reason why we used the 400 yard zero, is simply because it keeps most reasonable ranges in the center view of the scope.

If you are shooting a scope with a MOA-based reticle which adjusts in MOA, or, if you are shooting a scope with a mil-based reticle which adjusts in 0.1 or 0.2 mil-radian increments, you don't have to do conversions between MOA and milliradians. Just subtract the difference between the dope for the range you are shooting and the dope for the zero range.

With a MIL dot reticle, these hold over and under calculations can be used with any cartridge trajectory.

CHAPTER 15

“Manual calculations for environmentals (Density Altitude)”

For those of us who like to use the good ole, pencil to paper technique instead of technology, which is not a bad thing, especially when technology may fail at any moment when we need it the most. We need to understand how to accomplish the same thing our Kestrel can as close to perfect as possible.

There are a few factors that can impact the bullet in flight drastically that we can calculate accurately by hand when a Kestrel or an instrument similar to. These factors are wind and density altitude. Wind is a factor that can be estimated to a certain degree of accuracy through look and feel, and can become more accurate through practice as we discussed in previous chapters. Density altitude, or the corrected air/altitude that the bullet lives in can be easily calculated with simple math.

The Density Altitude calculation can be calculated using the formula:

Pressure altitude = (standard pressure - your current pressure setting) x 1,000 + field elevation

That’s a pretty simple formula since two of the variables will always be the same and the other two are easy enough to find. Let’s say our current altimeter setting is 29.45 and the field elevation is 5,000 feet. That means (29.92 - 29.45) x 1,000 + 5,000 = 5,470 feet.

Now let’s move on to step two, finding density altitude. Here’s the formula:

Density altitude = pressure altitude + [120 x (OAT - ISA Temp)]

Now, before your eyes glaze over, here’s how simple this formula is: We already have the value for pressure altitude from our last calculation; OAT is degrees Celsius read off our thermometer (let’s say it’s a balmy 35 °C today) and ISA Temp is always 15 °C at sea level. To find ISA standard temperature for a given altitude, here’s a rule of thumb: double the altitude, subtract 15 and place a - sign in front of it. (For example, to find ISA Temp at 10,000 feet, we multiply the altitude by 2 to get 20; we then subtract 15 to get 5; finally, we add a - sign to get -5.)

So, in the example above:

Density altitude = 5,470 + [120 x (35 - 5)]

Working out the math, our density altitude is 9,070 feet.

Sure this may seem confusing or lengthy at the moment, but I believe in not only relying on an instrument in our kit bag, but by knowing how to figure out the same thing our instrument can by hand.

CHAPTER 16

“Advanced Wind Estimation and Understanding”

Now that we have a basic understanding of wind, we can now take a look at how wind is affected in various environments in a more in depth manner. This chapter will be broken down into three sections:

-Mountain Wind

-Urban Wind

Each of these sections will give you an in depth look at how the wind is affected and influenced in different environments. Understanding how the wind is influenced in these environments will allow you to properly apply the correct DOPE to the rifle, thus increasing your hit percentage in different environments.

Most precision shooters, may it be in hunting, military, law enforcement, or competition, generally train in environments where the range is relatively flat, have range flags at designated locations, etc. The problems with ranges like this when training is that we become complacent, and the range is predictable when shooting in winds. Even though there is wind on the range, it can be easy to judge, no matter the speed. If you were to take the same shooters who train day in and day out on their comfortable range, to a mountainous range, how will they perform? I can guarantee with certainty, they will not perform the same as far as hit percentage goes.

Let’s take a look at how things change as far as wind, when we are in a mountainous area.

Mountain Winds:

Wind is the flow of gases on a large scale. Short bursts of high wind are known as gust. Strong winds of intermediate duration, typically around 1 minute, are known as squalls. Wind where the topography is generally rugged or mountainous, the wind flow is significantly interrupted. The wind circulation between mountains and valleys is the most important contributor to prevailing winds. Hills and valleys greatly distort the airflow by increasing friction between the atmosphere and landmass by acting as a

physical block to the flow, deflecting the wind parallel to the range just upstream of the topography, is known as a barrier jet. A barrier jet can increase the low level wind (where the shooter is) by 45%.

The wind direction also changes due to the contour of the land. Strong updrafts, downdrafts and eddies develop as the air flows over hills and down valleys.

Misleading wind direction

A misleading wind direction is caused by the swirling around the hill, or mountainous terrain feature and back up along the opposite side. Along with the misleading wind direction, turbulence is often found on the back side of the mountain as well. For example: if the wind is coming from the shooters 9 o'clock while the shooter is on top of a hill, the shooter will feel the wind coming from his 3 o'clock. Along with the misleading wind at his position, while on top of the hill, the winds will also be significantly higher than at ground level. This is very important for shooters that may be shooting from on top of a hill down below his/her position. Many shooters believe that they may be facing a crosswind, and typically judge for the higher crosswind at their position, when instead the wind that they feel is actually the wind coming around the hill and back up to them. Although the wind will be higher at their position, you can generally account mainly for the wind that you see at the base of the hill to the target.

If the target is in-between two hills, do not forget that the wind at the base in-between the two hills will be significantly higher. In some cases, the wind that you feel at the top of the hill, will match or be similar to the wind in-between the two hills.

Shooting in a Misleading wind:

If the target is along the opposite side of the mountain/hill from the wind direction, we can see that the wind has reversed. Depending on the size of the mountain/hill terrain feature, and its downward slope, instead of adjusting for our wind at our position, we need to adjust for the wind at both. Typically the wind that we feel and account for at our position can be divided by .25 or .45.

Increased wind speeds

Wind speeds will always be significantly higher at two points when shooting in mountainous/hilly environments. These two points will be the top of the mountain, as the wind sweeps up from ground level, and also in-between to mountainous terrain features. For example, imagine two hills, side-by-side, one at 9 o'clock and one at 3 o'clock. You have a wind coming from your 6 o'clock at 10 mph at the base of the two (ground level). The first wind you will feel is the at wind at your 12 o'clock. Knowing that this is a misleading wind, we can ignore it for now and acknowledge that the wind is actually coming from behind us. The wind at our position will be around 18-20 mph (depending on the elevation of the mountain/hill. As we look down our mountain along its side, we see the mirage slightly die down, almost by half (mid-range down the side). As we observe the environment in the valley between the two mountains/hills, we see that the wind has once again picked up, almost doubling the wind from what we see at mid-range.

Updraft winds

In some mountainous environments, shooters may observe an updraft along the base of a mountain terrain feature. Shooting from one hill/mountain top to the base of another, and the winds are coming from our 6 o'clock and traveling over and around your position and toward the mountain/hill in front of you, at the base of the mountain/hill in front, you may have an updraft as the winds sweep upward along the face on the terrain. Judging this wind can be very difficult, as far as the speed of the wind, which often looks like turbulence when observing mirage. Also note that this updraft occurs in unpredictable spurts of wind. Shooting in an updraft, the bullet impact can be significantly high, depending on the speed and angle of the upward slope.

Urban Winds:

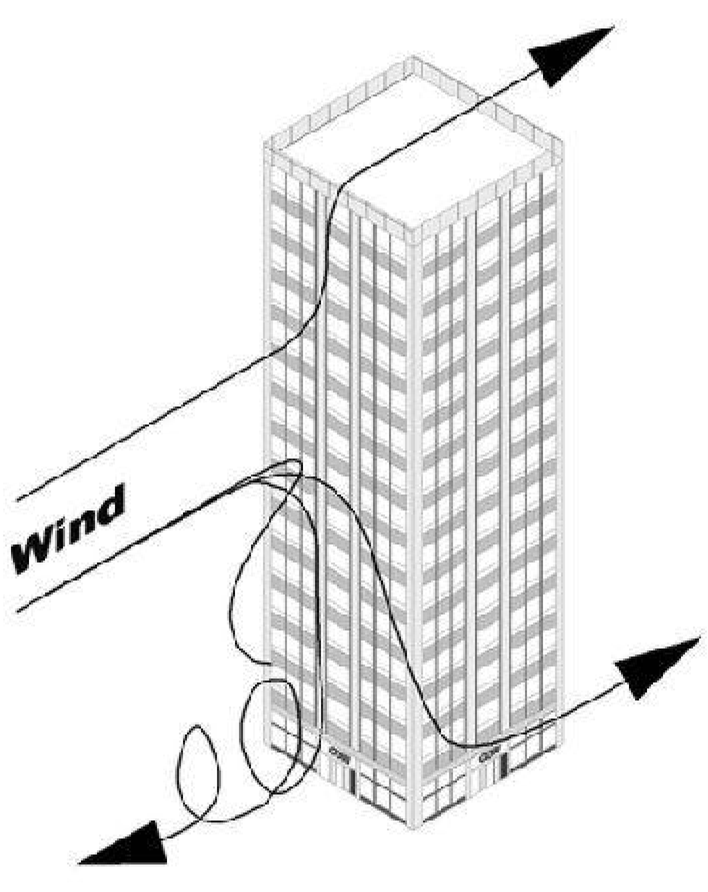
Shooting in urban environments, wind may seem to be misleading to some. In all actuality, the winds maneuver and behave in the almost the same manner as it would in a mountainous environment. The only difference being the various manmade structure shapes and sizes.

The way buildings are designed (generally rectangular or square shaped) the wind travels along them differently, making it somewhat difficult to properly read.

When wind interacts with a building, both positive and negative (i.e., suction) pressures occur simultaneously. Wind striking an exterior wall, forces the wind to flow around and upward/inward the sides and behind the structure, thus known as a negative pressure/suction. Shooting in between two large structures, one may judge the wind as a cross wind, when in actuality the shooter can call a “no wind” for that particular area, because the wind is being canceled out the two structures negative pressure winds.

A target located at or near a large structure, such as tall buildings, the shooter may observe two winds, on wind at the top of the building and another at the base. For example, take a look at the picture below:

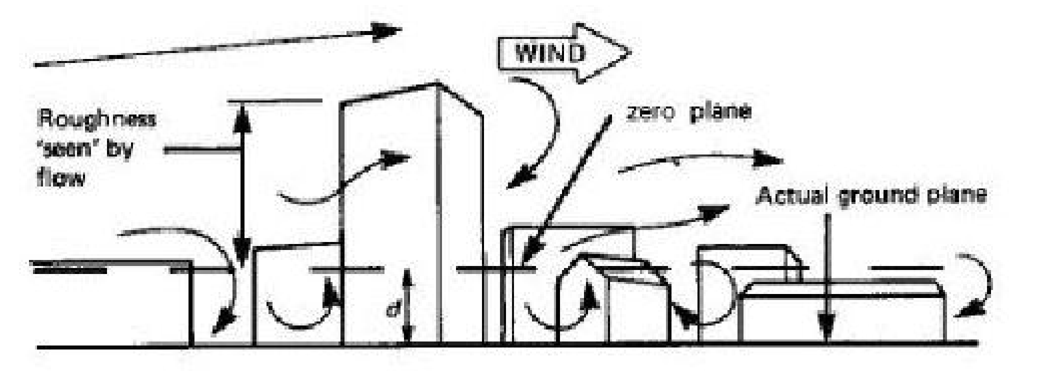
Effects of wind on structures



Note that in Fig. 1, the wind direction at the base of the building is opposite of the wind at the top. This change in direction must also be accounted for when taking precision shots and the target is at or near the base where the winds are originating.

When observing the wind on the exit side of multiple buildings and structures, we can see how the winds can become severely interrupted, to the point that the winds on the exit side at ground level have almost completely dissipated. The winds at mid-level and near the top of the buildings are almost undisrupted, maintaining some of its velocity and direction from the entry wind (decreasing the wind velocity by as much as 10-15 m.p.h.). See Fig 2. Note: observe the wind and its direction as it flows below the zero plane of the buildings.

Fig 2.



Targets that are being observed in-between two structures that are angled toward each other (fig. 3), the winds at that location and beyond before the wind disperses, can increase by double the amount of the wind on the entry side and exit side. This effect also occurs in mountainous environments as well, where the wind increases between two friction points.

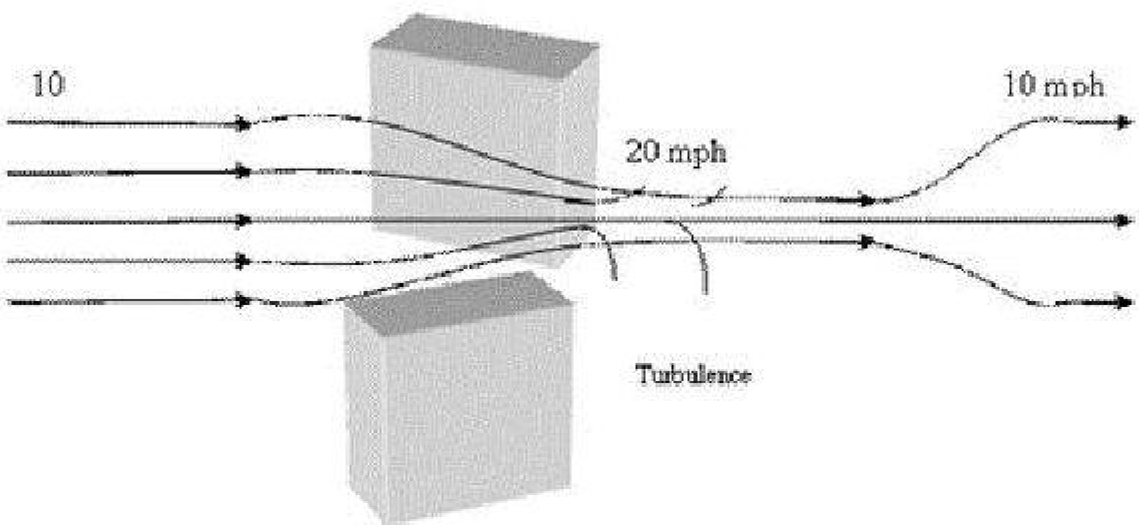


Fig. 3

In order to better understand the wind in an urban environment, below are two pictures that better illustrate how the wind maneuvers around a building. Note that the wind on the sides of the structure can double in velocity. This is important because when observing the mirage, you may notice a crosswind when in actuality you may be seeing the turbulent wind behind the building opposed to the wind on the sides.

(See fig. 4 and 5).

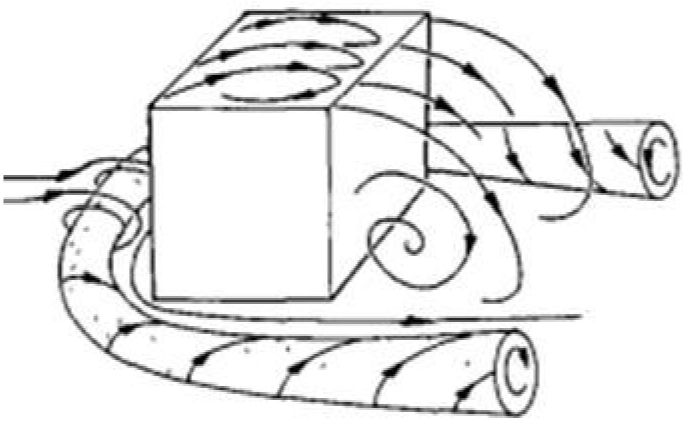


Fig.4

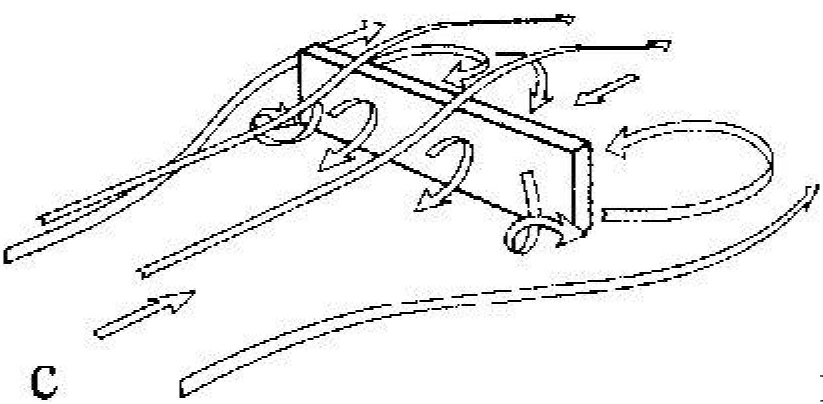


Fig. 5

CHAPTER 17

“Ballistics Through Various Objects”
Terminal Ballistics Continued

“These tests have been performed on a controlled environment. Do not attempt to perform these tests without a controlled environment or without the supervision of a professional.”

The majority of this information was conducted using the 175 gr. .308 HPBT projectile

This chapter we will discuss the bullets behavior once it impacts various objects. This term of ballistics is also known as Terminal ballistics. Terminal ballistics/wound ballistics is the study of the interaction of a projectile with its target, may it be flesh, steel, sand, concrete, glass, etc.

Just as we know how the projectile will maneuver through the air as it flies downrange, we also need to know how the bullet will behave once the projectile has hit a target. Some of our precision shooting may require us to shoot through an object in order for us to hit a target, or we may need to realize how our round will react once hitting a certain object. Terminal ballistics is the study of how a projectile behaves when it hits its target and transfers its kinetic energy to the target. The bullet’s design, as well as its impact velocity, plays a huge role in how the energy is transferred.

Below we can take a look at various objects and the way a projectile interacts within the object.

We will start with a common object such as wood or a tree branch, which is relevant to hunters or combat shooters. When shooting from a hide site, we may encounter our shot being interrupted by a tree branch of some size. Many of us military precision shooters are taught the “rule of thumb”. The “rule of thumb” relates to the size of the tree branch (no tree branch bigger than a thumb) in front of our barrel or in our bullets trajectory. If the branch is bigger than our thumb, we do not engage a target because a bullet will become “non-effective”, while a branch less than a thumbs circumference, the projectile will still be able to hit a desired target. While this may sound

legit, test have been conducted within the last year to show otherwise as shown below.

"Rule of Thumb" in similarities to a tree branch:

We recently did a test showing the deflection of a projectile (.308 175 grain HPBT) when it encounters various sized stick of wood representing a tree branch. The wood/branch was placed in front of an SR 25 barrel (18 inches), with a muzzle velocity of 2600 fps, shooting at a one inch dot placed on a standard cardboard IPSC target 100 yards away. The rifle and shooter were capable of shooting consistent ½ inch groups (5 rounds) at 100 yards from the prone position. We used various sizes in wooden dowels/branches, measuring ½", ¼", ¾", and 1".

Here are the results:

Range	Dowel Size	Dowel from muzzle	Impact Variation
100yrd	½"	18"	14"
100yrd	¼"	18"	4-8"
100yrd	¾"	18"	8-10"
100yrd	1"	18"	No shot on target

Looking at the information above, we can note that the projectile impact will drastically change depending on the dowel size, in some cases completely missing the entire IPSC cardboard target at 100 yards. Being that this information was only recorded at 100 yards, due to safety reasons, imagine if the target may have been at 200-300 yards and beyond.

After looking at the results, I have come to the conclusion that an object such as a tree branch, anywhere within 18 inches to within a few inches (or feet within the target), a precision shot should not be taken due to the unpredictability and inconsistency of the projectile.

Cinder block:

The results that we achieved from a 7.62 HPBT, 175 gr. against a cinderblock were not what we expected. A 175 gr, .308 HPBT projectile penetrated only 6 inches before dispersing and shattering at 25 and 200 meters. At 100 yards, it penetrated 8 inches before losing all of its energy and either falling to the ground. Knowing how the HPBT projectile works once it strikes an object, we decided to utilize .308 ball ammo to see how it would react when it strikes a cinderblock at 25, 100, and 200 meters (listed below) before falling and losing all kinetic energy.

Yards	Penetration
25	8 inches
100	10 inches
200	8 inches

Ballistic Jell (consistent with flesh): **(Examining variations of the .308).**

For the precision shooter (Hunter, L.E., or Military) that applies his/her skill on a flesh type target, ballistic gelatin gives us an in-depth look at how our rounds will perform on target.

Various types of ammunition are utilize by the precision shooter, one of the most common used by our military and law enforcement is the 175 gr. HPBT .308. By observing the projectile as it impacts ballistic gelatin, we can observe three very important factors within the gel, the temporary wound cavity, permanent wound cavity, and the overall penetration.

A bullet will destroy or damage any live tissue that it penetrates creating a wound channel. When this channel occurs, it will stretch and expand as it passes through.

Temporary Wound/Track Cavity:

The temporary wound cavity is exactly as it states, temporary. This wound cavity is the instantaneous displacement of tissue caused by the projectile as it travels through the flesh. This wound cavity is many, many times larger than the bullet diameter itself. The study of temporary wound cavity is still less understood due to lack of test material identical to live tissue. The temporary cavity only last a few milliseconds, and does not

directly result in incapacitation, instead this cavity will more than likely cause nothing more than a bruise.

An exception to the wound cavity is that a powerful temporary wound cavity that intersects with the spine, the blunt force trauma may cause the spinal cord to sever, or paralyze the target. High velocity fragmentation can also increase the effect of temporary cavitation. The fragments sheared from the bullet causes many small permanent cavities around the main entry point. The main mass of the bullet can then cause a truly massive amount of tearing as the perforated tissue is stretched.

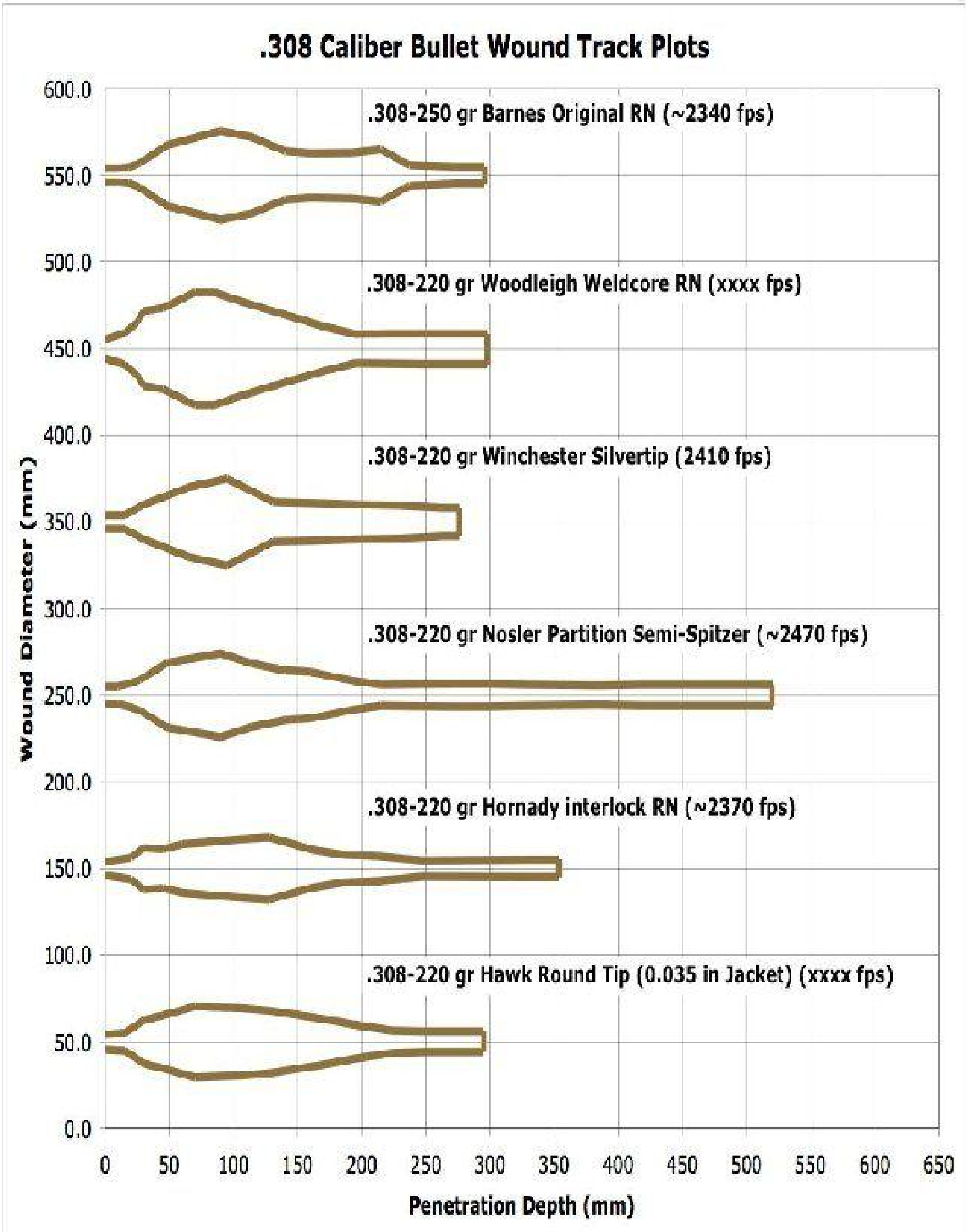
Permanent Cavity:

The permanent cavity is the channel/path left by the projectile as it passes through soft tissue and organs within its target as the tissues are expelled from the body.

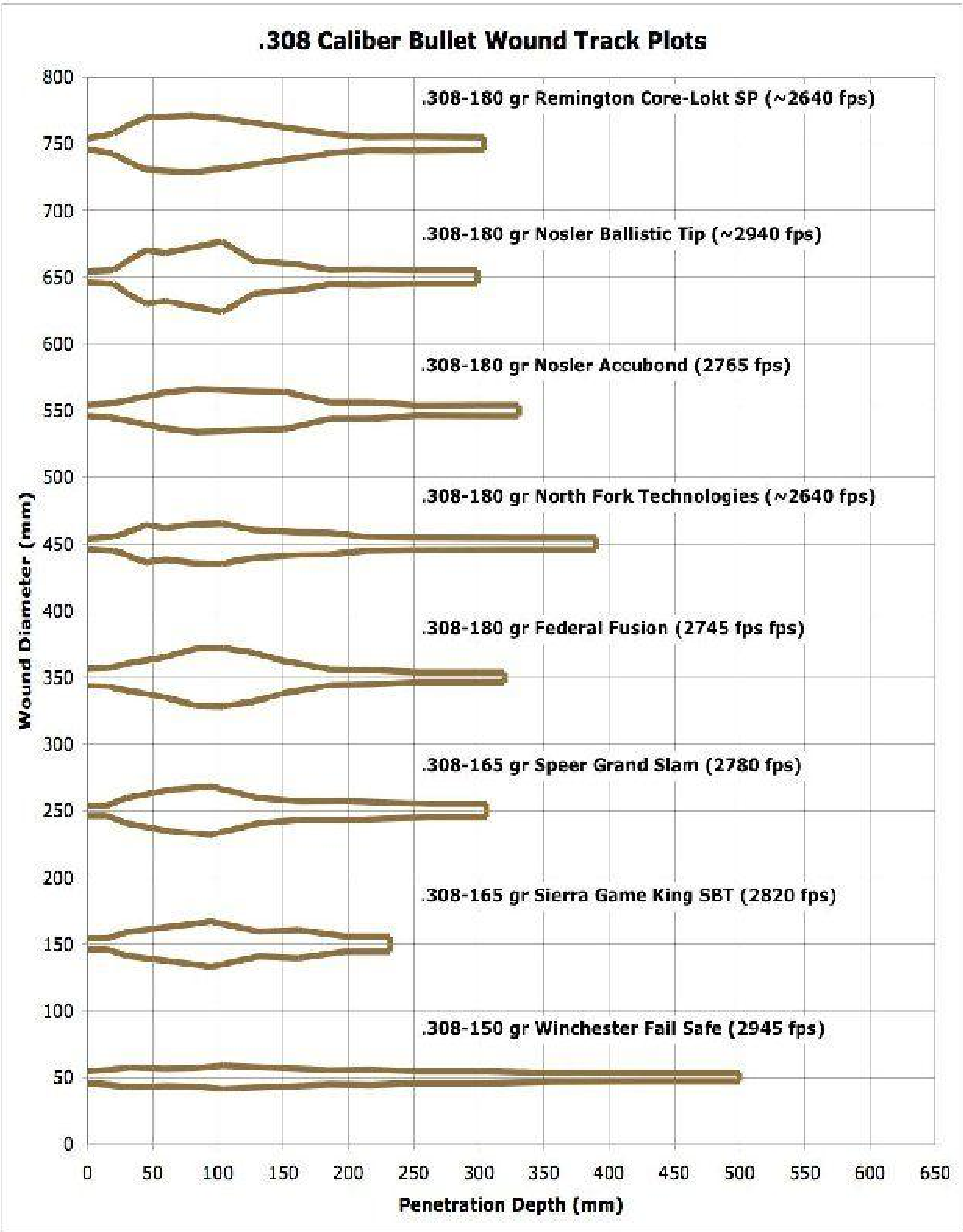
Penetration:

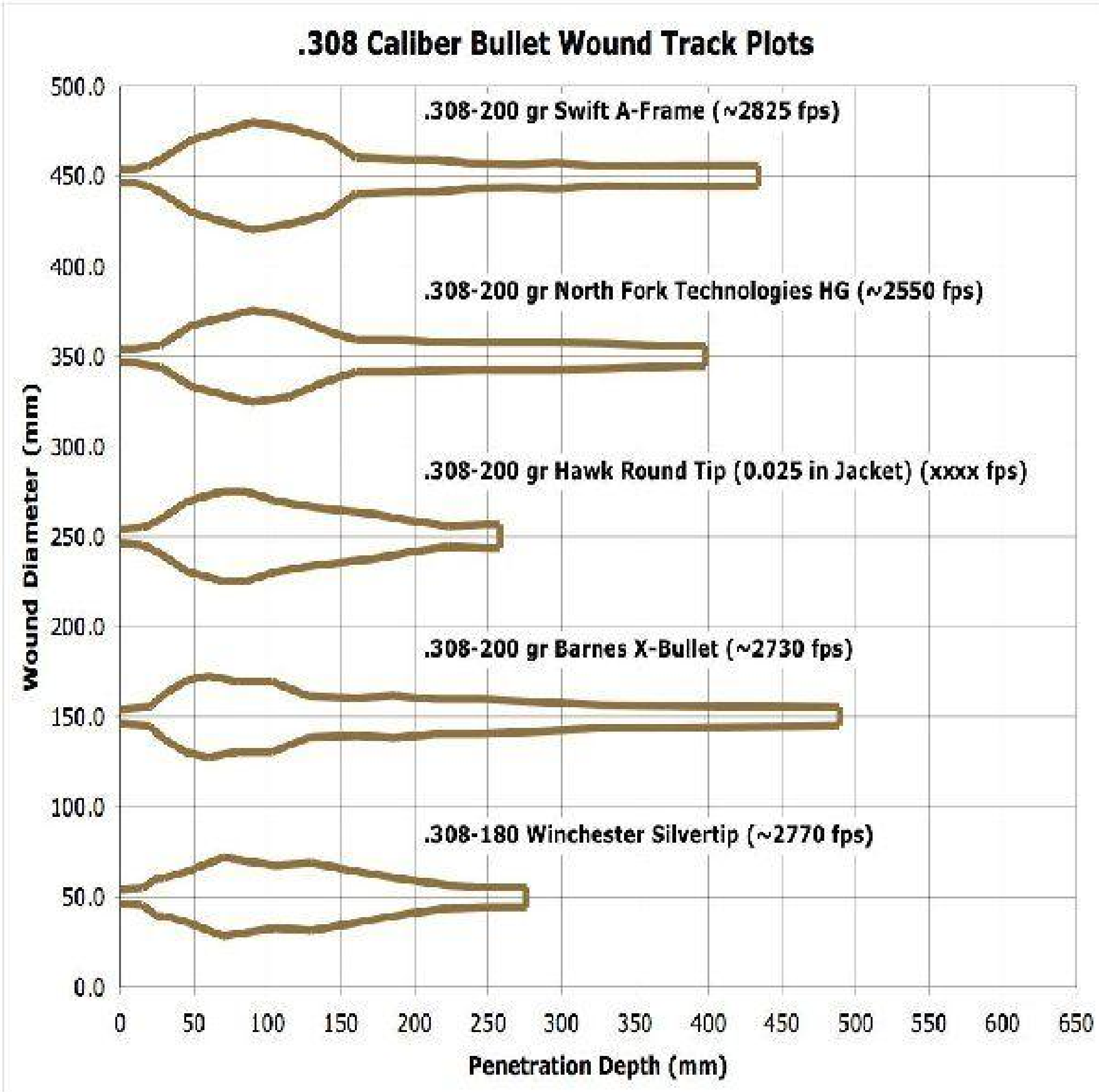
The penetration is the depth the projectile will travel within its target before the projectile exits.

On the next few pages are a few graphs that illustrate the wound cavities



.308 Caliber Bullet Wound Track Plots
.308-250 gr Barnes Original RN (~2340 fps)
.308-220 gr Woodleigh Weldcore RN (xxxx fps)
.308-220 gr Winchester Silvertip (2410 fps)
.308-220 gr Nosler Partition Semi-Spitzer (~2470 fps)
.308-220 gr Hornady interlock RN (~2370 fps)
.308-220 gr Hawk Round Tip (0.035 in Jacket) (xxxx fps)
Wound Diameter (mm)
Penetration Depth (mm)
600.0
550.0
500.0
450.0
400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
0
50
100
150
200
250
300
350
400
450
500
550
600
650


.308 Caliber Bullet Wound Track Plots
.308-180 gr Remington Core-Lokt SP (~2640 fps)
.308-180 gr Nosler Ballistic Tip (~2940 fps)
.308-180 gr Nosler Accubond (2765 fps)
.308-180 gr North Fork Technologies (~2640 fps)
.308-180 gr Federal Fusion (2745 fps fps)
.308-165 gr Speer Grand Slam (2780 fps)
.308-165 gr Sierra Game King SBT (2820 fps)
.308-150 gr Winchester Fail Safe (2945 fps)
Wound Diameter (mm)
Penetration Depth (mm)
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800


.308 Caliber Bullet Wound Track Plots
.308-200 gr Swift A-Frame (~2825 fps)
.308-200 gr North Fork Technologies HG (~2550 fps)
.308-200 gr Hawk Round Tip (0.025 in Jacket) (xxxx fps)
.308-200 gr Barnes X-Bullet (~2730 fps)
.308-180 Winchester Silvertip (~2770 fps)
Wound Diameter (mm)
Penetration Depth (mm)
500.0
450.0
400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
0 50 100 150 200 250 300 350 400 450 500 550 600 650

CHAPTER 18

“Cartridge Temperature and Accuracy”

“Because powder inside your cartridge burns at a higher rate when it's warm, and slower when it's cold, your rounds will strike low in cold weather and high in hot temperatures.”

Being a precision shooter, we need to account for every environmental change accordingly in order for us to make a precise shot downrange. Many of us may neglect to account for temperature change in our cartridge itself. When we buy a box of rifle ammunition and take a look at the box, we note the muzzle velocity and the bullet drops and put this information in our data book or calculator. We sometimes forget the fact that these bullets were manufactured in controlled environments, also known as standard conditions. A standard condition is: Altitude = sea level, Temperature = 59 degrees Fahrenheit, Atmospheric pressure = 29.53” of Hg, and a Relative humidity of 78% (standard conditions at Aberdeen test site).

The question that we need to ask ourselves is, “what happens to our bullet when we are not at standard conditions?”

Muzzle velocity developed by a cartridge combination depends on the temperature of the cartridge and its primer powder at the instant of firing the cartridge. This information can be important to precision shooters. Even though this is an interior ballistics effect, the variations in the muzzle velocity will cause a change in the exterior ballistics performance. Although the change in our standard conditions may not be as noticeable at close ranges, we can start to a change in D.O.P.E. at extended ranges, and ballistic coefficients as the standard conditions change.

We can take a look at some of the different variations in our data when the standard conditions change on the charts below.

Note that the data is taken from a .308 HPBT 165 grain with a sectional density of .248 and a ballistic coefficient of .363 at its highest muzzle velocity of 2600fps:

On the first test, we hold the Standard conditions:

Test NO. 1: Standard Conditions

Sea Level, 59 degrees F, BP= 29.53”, and 78% Humidity

Range (yards)	**Muzzle**	**100**	**200**	**300**	**400**	**500**
Velocity (FPS)	2600	2429	2264	2106	1953	1804
Traj. 100yd. Zero”	-1.5	0.0	-3.6	-13.3	-30.8	-57.9

Results: B.C.= .363

*******Test NO. 2: Higher Temperature*******

Sea Level, 89 degrees F, BP 29.53”, and 78% Humidity

Range (yards)	**Muzzle**	**100**	**200**	**300**	**400**	**500**
Velocity (FPS)	2600	2445	2281	2134	1981	1873
Traj. 100yd. Zero”	-1.5	0.0	-3.5	-13.1	-30.1	-56.4

Results: Due to less dense air (warmer Temp.) calculated B.C. is .380

Test NO. 3: Higher Barometric Pressure

Sea level, 59 degrees F, BP 31.00”, and 78% Humidity

Range (yards)	**Muzzle**	**100**	**200**	**300**	**400**	**500**
Velocity (FPS)	2600	2413	2225	2070	1902	1782
Traj. 100yd. Zero”	-1.5	0.0	-3.6	-13.6	-31.5	-59.5

Results: Denser air (Higher BP., the calculated B.C. is .345

Looking at the higher temperatures as opposed to the standard conditions on our bullet cartridge, we can see that the B.C. has changed by .017. The B.C. change may not seem like a lot, but note that this change has occurred with only a temperature change of on 30 degrees, and changed the impact on a 500 yard target of plus 1.5 inches.

If we were to leave a box of ammo in a vehicle for several hours in high temperatures, and our ammunition temperature increases by as much as 70 -80 degrees, we may see a variation (positive) by as much as 2.5-3.5 inches at 500 yards. The increase in impact will grow as the distance increases, this may become a problem when the target is partially obscured. The increase in elevation will not increase exponentially. A rule of thumb, applies to the "difference in temperature elevation drop and rise." The rule of thumb for .308 and .30 caliber rounds are:

When the temperature changes 20 degrees form your zero temp (as applied to the cartridge itself), apply 1MOA at 300 yards.

When the temperature changes 15degrees form your zero temp (as applied to the cartridge itself), apply 1MOA at 600 yards.

When the temperature changes 10 degrees form your zero temp (as applied to the cartridge itself), apply 1MOA at 1000 yards.

The table below was conducted by the U.S. Army in regards to bullet drop and Muzzle velocity when the cartridge temperature changes. The bullet drop and muzzle velocity was tested on a 600 yard target with a 200 yard zero.

Degrees	M.V.	Bullet Drop at 600 yd (200 yd Zero)
-10	2400	-109"
+25	2500	-100"
+59	2600	-91"
+100	2700	-84"

The formula below can be used to equate for a temperature in not only the cartridge, but for the outside temperature as well.

Degrees +/- 60 Degree Standard x Distance (hundreds of yds.)

(Divided by 10 (Math Constant) =

Range Change for Temperature

When the temperature is less than 60 degrees, add the result to your actual target distance; when it's above 60 degrees, subtract this distance from the actual distance.

For example: The temperature is 90 degrees F. (30 degrees hotter than 60-degree F. standard), and your target is 500

Yards away.

30 x 5

------------ = 15

10

Deduct this distance (15 yards) from the 500 yards, and then set your sights as if the target is 485 yards away, aim dead-on, and fire.

CHAPTER 19

“Shooter Tables”

308 Winchester 168gr SMK				
Range	Drop		10mph Wind	
(yd)	(MOA)	(mil)	(MOA)	(mil)
10	-14.1	-4.1	-0.7	-0.2
25	-3.6	-1	-0.6	-0.2
50	-0.5	-0.2	-0.4	-0.1
75	0	0	-0.2	-0.1
125	-0.3	-0.1	0.2	0.1
150	-0.7	-0.2	0.4	0.1
200	-1.8	-0.5	0.8	0.2
250	-3.1	-0.9	1.2	0.4
300	-4.6	-1.3	1.6	0.5
350	-6.2	-1.8	2.1	0.6
400	-7.9	-2.3	2.6	0.7
450	-9.7	-2.8	3.1	0.9
500	-11.6	-3.4	3.6	1
525	-12.6	-3.7	3.8	1.1
550	-13.7	-4	4.1	1.2
575	-14.8	-4.3	4.4	1.3
600	-15.9	-4.6	4.7	1.4

308 Win 168gr SMK		
Range	Drop	Wind
(yd)	(MOA)	(MOA)
10	-14.1	-0.7
25	-3.6	-0.6
50	-0.5	-0.4
75	0	-0.2
125	-0.3	0.2
150	-0.7	0.4
200	-1.8	0.8
250	-3.1	1.2
300	-4.6	1.6
350	-6.2	2.1
400	-7.9	2.6
450	-9.7	3.1
500	-11.6	3.6
525	-12.6	3.8
550	-13.7	4.1
575	-14.8	4.4
600	-15.9	4.7

308 Win 168gr SMK		
Range	Drop	Wind
(yd)	(mil)	(mil)
10	-4.1	-0.2
25	-1	-0.2
50	-0.2	-0.1
75	0	-0.1
125	-0.1	0.1
150	-0.2	0.1
200	-0.5	0.2
250	-0.9	0.4
300	-1.3	0.5
350	-1.8	0.6
400	-2.3	0.7
450	-2.8	0.9
500	-3.4	1
525	-3.7	1.1
550	-4	1.2
575	-4.3	1.3
600	-4.6	1.4

RANGE (METERS)	SLANT DEGREES 5	10	15	20	25	30	35	40	45	50	55	60
100	.01	.04	.09	.16	.25	.36	.49	.63	.79	.97	1.2	1.4
200	.03	.09	.2	.34	.53	.76	1.	1.3	1.7	2.	2.4	2.9
300	.03	.1	.3	.5	.9	1.2	1.6	2.1	2.7	3.2	3.9	4.5
400	.05	.19	.43	.76	1.2	1.7	2.3	2.9	3.7	4.5	5.4	6.3
500	.06	.26	.57	1.	1.6	2.3	3.	3.9	4.9	6.	7.2	8.4
600	.08	.31	.73	1.3	2.	2.9	3.9	5.	6.3	7.7	9.2	10.7
700	.1	.4	.9	1.6	2.5	3.6	4.9	6.3	7.9	9.6	11.5	13.4
800	.13	.5	1.	2.	3.	4.4	5.9	7.7	9.6	11.7	14.	16.4
900	.15	.6	1.3	2.4	3.7	5.3	7.2	9.3	11.6	14.1	16.9	19.8
1,000	.2	.7	1.6	2.8	4.5	6.4	8.6	11.	13.9	16.9	20.2	23.7

*RANGE GIVEN IS SLANT RANGE (METERS), NOT MAP DISTANCE.

Table 3-3. Bullet rise at given angle and range in minutes.

TABLE FOR 6-FOOT MAN		
HEIGHT IN MILS	STANDING	SITTING/ KNEELING
1	2000	1000
1.5	1333	666

2	1000	500
2.5	800	400
3	666	333
3.5	571	286
4	500	250
4.5	444	222
5	400	200
5.5	364	182
6	333	167
6.5	308	154
7	286	143
TABLE FOR 5-FOOT 6-INCH MAN		
HEIGHT IN MILS	STANDING	SITTING/ KNEELING
1	1800	900
1.5	1200	600
2	900	450
2.5	750	375
3	600	300
3.5	514	257
4	450	225
4.5	400	200
5	360	180
5.5	327	164
6	300	150
6.5	277	139

Table 4-1. Range estimation table.

INDEX

Index

REFERENCES/ACKNOWLEDGMENTS

Rifles Only (Jacob Bynum)

http://www.arcanamavens.com/ Lindy Sisk

FM 23-10 Sniper Manual (Pictures)

***For a visual of how these fundamentals and skill sets are applied, be sure to check out the D.V.D. at www.riflesonly.com located in the websites Pro Shop. ***

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